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STUDIES IN THE HYDROPHYTES OF NAGPUR

A Preliminary Survey

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Introduction

Detailed systematic and ecological study of the hydrophytes has been pursued for a long time in Western Countries. Such investigations have yielded useful and significant data on the floristic composition, distribution, ecology and other aspects of this interesting group of plants. The monumental work of Arber (1920) and the comprehensive volumes on the systematics of the water plants of the United States of America by Fassett (1940) and Muenscher (1944) are instances of the progress made in the West as regards our knowledge of the hydrophytes.

In India, this subject has not received enough attention so far, with the result that our knowledge of the hydrophytes as a group is far from complete. Biswas and Calder's (1937) book on the water and marsh plants is the only contribution, so far, dealing exclusively with the hydrophytes of India. Contributions on the biology and other aspects of some Indian hydrophytic species have appeared from time to time, but for the brief references to the hydrophytic vegetation of certain regions by Misra (1946), and a few others, a comprehensive work on the subject is indeed conspicuous by its absence. Aquatic and marsh species have no doubt been described in various floras. Particular mention must be made of Haines's (1925) Flora in which he gives, in the introduction, a general survey of the character and ecology of the aquatic and marsh flora of Bihar and Orissa.

No contribution, as far as the author is aware, has appeared so far, dealing with the hydrophytes of Madhya Pradesh. Indeed, the systematic study of the flora in this State has been very much neglected. Only partial lists have been prepared by Graham (1911), Haines (1916)

and Witt (1916). Recently Hewetson (1951) has done well to draw the attention of botanists to this gap in our knowledge and has appealed for the preparation of a Flora for Madhya Pradesh.

It was, therefore, thought advisable to make a critical survey of the hydrophytes of the various parts of Madhya Pradesh. A beginning has been made with the study of the aquatic and marsh vegetation of Nagpur. The author has made a number of excursions since April, 1952 and the results of the preliminary survey are presented in this paper. The floristic composition and distribution of this group is discussed here. It is intended to give an account of their ecology, phenology and physiological anatomy in a series of contributions later on.

Locality

The locality selected for the study comprises an area of about 100 square miles, with the Government College of Science, Nagpur as the centre. The accompanying map shows the area surveyed so far.

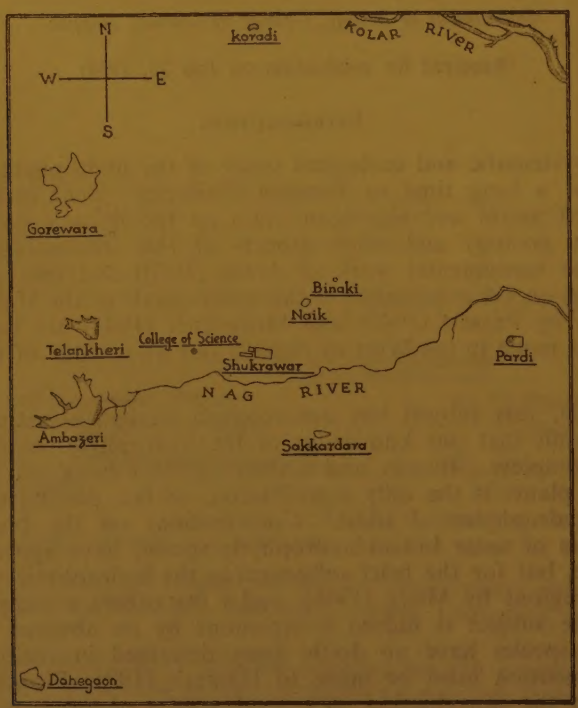

Fig. 1. Map showing the location of important habitats of hydrophytes.

Nagpur is situated roughly in the centre of Madhya Pradesh. It is 1010·3 feet above sea-level. Table I gives the clima ic data for the year 1952, the period during which most of the collections were made. The annual rainfall was particularly low during this year. The

TABLE I

Climatic data of Nagpur

(Sonegaon Aerodrome : Height above sea-level—1010.3 ft.)

Month	Temperature in 0° F.		Relative Humidity %		Rainfall in inches
	Mean Maximum	Mean Minimum	At 0830 Hr. I.S.T.	At 1730 Hr. I.S.T.	
January ..	85·9	53·3	49	27	0·00
February ..	90·5	60·1	53	27	0·50
March ..	96·7	64·2	37	22	0·58
April ..	105·8	77·8	32	18	0·04
May ..	110·9	85·6	33	19	Trace
June ..	102·5	81·6	52	40	3·30
July ..	90·5	75·5	78	66	10·28
August ..	86·3	74·5	79	67	9·05
September ..	89·8	74·2	78	71	2·06
October ..	92·4	67·5	61	49	0·62
November ..	87·0	54·7	48	34	0·00
December ..	85·4	55·7	63	49	Trace
Year ..	93·6	68·7	55	41	26·83

average rainfall for the place is 40 to 45 inches, nearly the whole of which falls between June and September. The temperature may reach a maximum of 115° F. in the month of May, while it may show a minimum of 40° to 45° F. in the month of January.

The Deccan Traps, which occupy large areas, weather at places with characteristic spheroidal exfoliation, which gives rise to large rounded boulders on the outcrops. The traps give rise to either a deep brown to rich red soil or to black cotton soil. At a few places, the intertrappean beds are also exposed. They comprise cherts, impure lime-stones and pyroclastic materials. These on weathering give rise to calcareous and siliceous soils.

HABITATS

The common habitats of hydrophytes in this area are a number of lakes and tanks, natural and artificial, the rivers Nag and Kolar and their tributaries, temporary ponds and deserted wells. The map shows the position and direction of the important lakes and rivers.

TABLE II

Detailed Distribution of Hydrophytes in the various habitats of Nagpur

No.	SPECIES	HABITATS												
		1	2	3	4	5	6	7	8	9	10	11	12	13
1	*Nymphæa Lotus* Linn. ..	–	–	×	–	×	–	×	–	–	×	–	–	–
2	*Nelumbium speciosum* Willd. ..	–	–	×	–	×	–	×	–	–	×	–	–	–
3	*Cleome chelidonii* Linn. ..	×	×	–	–	–	–	–	–	–	–	–	–	×
4	*Malachra capitata* Linn. ..	–	–	–	–	–	–	–	–	–	–	×	–	–
5	*Sesbania aculeata* Poir. ..	–	×	–	–	×	–	–	–	–	–	×	–	×
6	*Ammania baccifera* Linn. ..	–	×	–	–	–	–	–	–	–	–	×	×	×
7	*A. pentandra* Roxb. ..	–	×	–	–	–	–	–	–	–	–	×	×	×
8	*Jussiæa suffruticosa* Linn. ..	–	–	–	–	–	–	–	–	–	–	×	–	–
9	*Adenostemma viscosum* Forst. ..	–	–	–	–	–	–	–	–	–	–	×	–	–
10	*Cæsulia axillaris* Roxb. ..	×	×	–	–	×	–	×	–	–	×	×	–	×
11	*Xanthium strumarium* Linn. ..	–	×	–	–	–	–	–	–	–	–	×	×	×
12	*Eclipta erecta* Linn. ..	×	×	–	–	×	×	×	–	–	×	×	×	×
13	*Exacum pedunculatum* Linn. ..	–	–	–	–	–	–	–	–	×	×	×	×	–
14	*Canscora decurrens* Dalz. ..	–	–	–	–	–	–	–	–	×	–	×	×	–
15	*Limnanthemum cristatum* Griesb. ..	–	–	×	–	×	–	×	–	–	×	–	–	–
16	*Ipomæa aquatica* Forsk. ..	–	–	–	–	×	×	×	–	–	×	×	–	–

17	*Moniera cuneifolia* Michaux. ..	×	×	–	–	–	–	–	–	–	–	×	×	–
18	*Limnophila heterophylla* Woodr. ..	–	×	–	–	–	–	–	–	–	×	×	–	–
19	*Vandellia crustacea* Benth. ..	–	–	×	–	–	–	–	–	–	–	–	–	×
20	*Bonnaya oppositifolia* Spreng. ..	–	–	–	–	–	–	–	–	–	–	–	–	×
21	*Utricularia* sp. ..	–	–	–	–	×	–	–	–	–	×	×	–	–
22	*U. stellaris* Linn. ..	–	–	–	–	–	–	–	–	×	–	–	–	–
23	*Asteracantha longifolia* Nees. ..	–	×	–	–	×	×	×	–	–	×	×	–	×
24	*Hygrophila angustifolia* R. Br.	–	–	–	–	–	–	–	–	–	–	×	–	–
25	*Lippia nodiflora* Michaux. ..	×	×	–	–	×	–	–	×	–	×	–	–	–
26	*Alternanthera triandra* Lam. ..	×	–	–	–	×	×	–	–	–	×	×	–	×
27	*Polygonum glabrum* Willd. ..	–	×	–	–	–	–	–	–	–	–	–	×	–
28	*P. plebejum* R. Br. ..	×	×	–	–	–	–	–	–	–	–	–	–	–
29	*Ceratophyllum demersum* Linn. ..	–	–	–	–	×	–	×	–	–	×	–	–	–
30	*Hydrilla verticillata* Presl. ..	×	×	×	–	×	–	×	×	×	×	×	–	×
31	*Lagarosiphon Roxburghii* Benth. ..	×	×	–	–	×	–	–	–	×	–	×	×	×
32	*Vallisneria spiralis* Linn. ..	×	×	×	–	–	–	–	×	×	–	×	×	×
33	*Ottelia alismoides* Pers. ..	×	–	–	–	×	–	–	–	×	×	×	–	–
34	*Eichhornia crassipes* Solms. ..	–	–	–	×	–	×	–	–	–	–	×	–	–
35	*Commelina benghalensis* Linn. ..	×	×	–	–	×	–	–	–	–	–	×	–	×
36	*Cyanotis axillaris* Sch. ..	×	×	–	–	×	–	–	–	–	–	×	–	×
37	*Typha angustata* Bory and Chaub. ..	–	×	–	–	–	–	–	–	×	×	×	–	×
38	*Pistia Stratiotes* Linn. ..	–	–	–	×	×	–	–	–	–	–	–	–	–

TABLE II—(*Contd.*)

No.	SPECIES	HABITATS												
		1	2	3	4	5	6	7	8	9	10	11	12	13
39	*Lemna minor* Linn. ..	–	–	–	–	×	–	–	–	–	×	–	–	×
40	*Spirodela polyrhiza* Schleid. ..	–	–	–	–	×	×	×	–	–	×	–	–	×
41	*Aponogeton monostachyon* Linn. ..	–	–	–	–	–	–	×	–	–	–	–	–	–
42	*Potamogeton indicus* Roxb. ..	×	–	–	–	–	–	–	–	×	×	×	–	–
43	*P. crispus* Linn. ..	×	–	–	–	–	–	–	–	–	–	–	–	–
44	*P. pectinatus* Linn. ..	×	–	–	–	–	–	–	×	×	–	–	×	–
45	*Naias minor* Allione. ..	×	–	–	–	×	–	×	–	–	×	×	×	×
46	*Eriocaulon* sp. ..	–	–	–	–	–	–	–	–	–	–	×	–	–
47	*Fimbristylis* sp. ..	–	–	–	–	–	–	–	–	×	–	×	–	–
48	*Eleocharis* sp. ..	–	–	–	–	–	–	–	–	×	–	×	–	–
49	*Scirpus* sp. ..	–	–	–	–	–	–	–	–	×	–	×	–	–
50	*Hygrorhiza aristata* Nees. ..	–	–	–	–	–	–	–	–	–	×	–	×	–
51	*Equisetum* sp. ..	–	–	–	–	–	–	–	–	–	–	×	×	–
52	*Marsilea quadrifolia* L. ..	–	–	–	–	×	–	–	–	–	×	×	–	×
53	*Azolla* sp. ..	–	–	–	–	×	–	×	–	–	×	–	–	–

1. Ambazeri; 2. Gorewara; 3. Telankheri; 4. Shukrawar; 5. Sakkardara; 6. Naik; 7. Binaki; 8. Pardi; 9. Dahegaon; 10. Koradi; 11. Nag River; 12. Kolar River; 13. Deserted Wells and Ponds. ×, Present; –, Absent.

Out of these, the Ambazeri and the Gorewara lakes are reservoirs supplying drinking water to the town. The water is, therefore, constantly drained out. These are perennial tanks and do not dry up even in the hottest part of the summer, though the water level may go down considerably. Ambazeri has a full capacity of 1,700 million gallons of water out of which normally two million gallons are drawn from this source daily. Gorewara has a full capacity of 1,800 million gallons. It has a catchment area of 11 square miles. Normally, three million gallons are pumped daily. A rich carpet vegetation consisting of *Lippia nodiflora, Moniera cuneifolia* (*Herpestis Monniera*) and *Polygonum plebejum* flourishes on their shores. *Cleome chelidonii* also grows luxuriantly on the margins of both these lakes.

Other perennial lakes are Pardi and Dahegaon. These are frequented by people who swim in their waters and wash clothes on their banks and cattle graze and are washed near the shallower margins. Dahegaon is a comparatively secluded spot and supports a rich vegetation despite the biotic influence. There is luxuriant growth of *Potamogeton pectinatus* and *Lagarosiphon Roxburghii. Utricularia stellaris* is found exclusively in this habitat.

Telankheri is a swimming tank that dries out almost completely in summer. It shows very poor vegetation in its waters. However, there is a garden adjoining the tank. Here, in artificial aquaria, *Nymphæa Lotus, Nelumbium speciosum, Hydrilla verticillata, Limnanthemum cristatum* and other forms grow in a fairly natural condition. The swimming pool in the garden supports a luxuriant growth of *Naias minor.*

The Binaki and Shukrawar tanks are situated in or near the heart of the city and are, therefore, under great biotic influence. A portion of the Shukrawar tank supplies water to the local mills which release back their waste products into the tank again. The shallower margins of this tank support a poor growth of *Eichhornia crassipes.*

The Binaki, Naik and Sakkardara lakes dry up completely by December. Sakkardara shows a characteristic hydrophytic vegetation of *Nymphæa Lotus-Nelumbium speciosum-Limnanthemum cristatum —Ipomæa aquatica* association. Binaki lake presents a beautiful sight of the copper-coloured floating *Azolla* sp., associated with green fronds of *Spirodela polyrhiza.* It also supports a rich growth of submerged forms, *viz., Ceratophyllum demersum* and *Naias minor. Aponogeton monostachyon* has been reported only from this locality. Secluded corners of the Naik lake support nitrophilous species like *Asteracantha longifolia, Ipomæa aquatica* and *Eichhornia crassipes.*

The Koradi lake supports a rich hydrophytic flora. *Nelumbium speciosum, Eclipta erecta, Ipomæa aquatica, Asteracantha longifolia, Hydrilla verticillata, Typha angustata, Lemna minor, Spirodela polyrhiza, Naias minor* and *Hygrorhiza aristata* among others have been collected from this place.

The Nag River flows through the entire length of the city, taking its origin from the Ambazeri lake which feeds it. At places, during

its course, much of the refuse and night soil of the city is emptied into its waters and the river forms stagnant pools of stinking water. These spots support nitrophilous species like *Eichhornia crassipes* and *Eclipta erecta*. At other places the river shows a healthy growth of *Ottelia alismoides*, *Vallisneria spiralis*, *Hydrilla verticillata*, *Potamogeton indicus*, *Ipomæa aquatica*, *Lagarosiphon Roxburghii* and *Utricularia* sp. in its waters, while the shallow margins and wet banks are covered with *Lippia nodiflora*, *Moniera cuneifolia*, *Jussiæa suffruticosa*, *Asteracantha longifolia*, *Ammania baccifera*, *Equisetum* sp. and *Marsilea quadrifolia*. Shallow regions of the river-bed are occupied by thick formations of *Typha angustata*, *Adenostemma viscosum* and *Scirpus* sp.

The Kolar River shows *Vallisneria spiralis*, *Hydrilla verticillata* and *Lagarosiphon Roxburghii* in its waters, while the banks at places show a very healthy growth of *Equisetum* sp.

Enumeration of Species

The concept of hydrophytes or water plants is subject to various interpretations. It is difficult to make a definition that could be strictly adhered to. The author has followed the definition of Weaver and Clements (1929), according to which:

"Hydrophytes are plants that grow in water, in soil covered with water, or in soil that is usually saturated with water."

On the basis of the author's own collections, the following taxonomic data for the hydrophytes of Nagpur can be given at the present stage:—

Phylum	Class	Families	Genera	Species
Pteridophyta	Equisetales ..	1	1	1
	Hydropteridineæ ..	2	2	2
Angiosperms	Dicotyledons ..	16	26	29
	Monocotyledons ..	12	19	21

Angiosperms

Dicotyledons

I. Nymphæaceæ .. *Nymphæa Lotus* Linn.
Nelumbium speciosum Willd.

II. Capparidaceæ .. *Cleome chelidonii* Linn.

III. Malvaceæ .. *Malachra capitata* Linn.

IV. Leguminosæ Papilionaceæ .. *Sesbania aculeata* Poir.

V. Lythraceæ .. *Ammania baccifera* Linn.
A. pentandra Roxb.

VI. Onagraceæ .. *Jussiæa suffruticosa* Linn.

VII.	Compositæ	.. *Adenostemma viscosum* Forst. *Cæsulia axillaris* Roxb. *Xanthium strumarium* Linn. *Eclipta erecta* Linn.
VIII.	Gentianaceæ	.. *Exacum pedunculatum* Linn. *Canscora decurrens* Dalz. *Limnanthemum cristatum* Griesb.
IX.	Convolvulaceæ	.. *Ipomæa aquatica* Forsk.
X.	Scrophulariaceæ	.. *Moniera cuneifolia* Michaux. (*Herpestis Monniera* H.B. & K.) *Limnophila heterophylla* Woodr. *Vandellia crustacea* Benth. *Bonnaya oppositifolia* Spreng.
XI.	Lentibulariaceæ	.. *Utricularia* sp. *U. stellaris* Linn.
XII.	Acanthaceæ	.. *Asteracantha longifolia* Nees. *Hygrophila angustifolia* R. Br.
XIII.	Verbenaceæ	.. *Lippia nodiflora* Michaux.
XIV.	Amarantaceæ	.. *Alternanthera triandra* Lam. (*A. sessilis* R. Br.)
XV.	Polygonaceæ	.. *Polygonum glabrum* Willd. *P. plebejum* R. Br.
XVI.	Ceratophyllaceæ	.. *Ceratophyllum demersum* Linn.
Monocotyledons		
XVII.	Hydrocharitaceæ	.. *Hydrilla verticillata* Presl. *Lagarosiphon Roxburghii* Benth. *Vallisneria spiralis* Linn. *Ottelia alismoides* Pers.
XVIII.	Pontederiaceæ	.. *Eichhornia crassipes* Solms.
XIX.	Commelinaceæ	.. *Commelina benghalensis* Linn. *Cyanotis axillaris* Sch.
XX.	Typhaceæ	.. *Typha angustata* Bory and Chaub.
XXI.	Araceæ	.. *Pistia Stratiotes* Linn.
XXII.	Lemnaceæ	.. *Lemna minor* Linn. *Spirodela polyrhiza* Schleid.
XXIII.	Aponogetonaceæ	.. *Aponogeton monostachyon* Linn.
XXIV.	Potamogetonaceæ	.. *Potamogeton indicus* Roxb. *P. crispus* Linn. *P. pectinatus* Linn.
XXV.	Naiadaceæ	.. *Naias minor* Allione.
XXVI.	Eriocaulaceæ	.. *Eriocaulon* sp.

XXVII.	Cyperaceæ	..	*Fimbristylis* sp. *Eleocharis* sp. *Scirpus* sp.
XXVIII.	Gramineæ	..	*Hygrorhiza aristata* Nees.

PTERIDOPHYTA

I.	Equisetales	..	*Equisetum* sp.
II.	Hydropteridineæ		
	Marsileaceæ	..	*Marsilea quadrifolia* L.
	Salviniaceæ	..	*Azolla* sp.

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THE MORPHOLOGY AND ECOLOGY OF *MOLLUGO CERVIANA* SER.

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Introduction

According to Tansley (1949) the progress in ecology during the next few decades would be mainly due to intelligently directed work in the field of autecology. Puri (1949) has also laid emphasis on the autecological studies of crop plants and weeds. A beginning in this direction was made by Misra and Siva Rao in 1948, and this has been followed by Srivastava and Tandon (1951), Bakshi (1952 *b*), Bakshi and Kapil (1952), and Pandeya (1953).

The most important contributions to the study of the vegetation of the Indian desert are by Blatter and Hallberg (1918–21) and Sabnis (1921–24, 1929). A few recent attempts include those by Mulay and Ratnam (1950), Ramachandran (1950), Ratnam (1951), Sarup (1951, 1952), Sankhala (1951), and Biswas and Rao (1953). A synecological study of a small tract of vegetation in Pilani (Rajasthan) has been made by Ratnam and Joshi (1952). Bakshi (1954) has recently studied the vegetation of Pilani and its neighbourhood. A glance at these would bear testimony to the fact that no aspect of the study of the Indian desert species has been so much neglected as the autecological. The present study is the first of a series undertaken to remedy this omission.

The genus *Mollugo* Linn. at Pilani is represented by three species, *M. cerviana* Ser., *M. nudicaulis* Lamk. and *M. hirta* Thunb. (Bakshi, 1954). Of these, the first two appear during the rainy season. They exhibit remarkable differences as regards their habitats. Hence an autecological study of both was undertaken. A communication embodying the results of investigation on *M. nudicaulis* has appeared separately (Bakshi and Kapil, 1952), while the present paper deals with *M. cerviana*.

M. cerviana has been reported from the drier and warmer regions of Asia, Africa and Australia. In India it is fairly common in most parts with the exception of Bengal (Hooker, 1879; Duthie, 1918). From Rajasthan, Blatter and Hallberg (1918–21) have collected it at Jodhpur, Bhikamkar, Balarwa, Phalodi, Barmer, Loharki, Jaisalmer, Devikot and Vinjorai dunes (Fig. 1). Ratnam and Joshi (1952) and Bakshi (1954) have recorded it from Pilani where it occurs mostly on

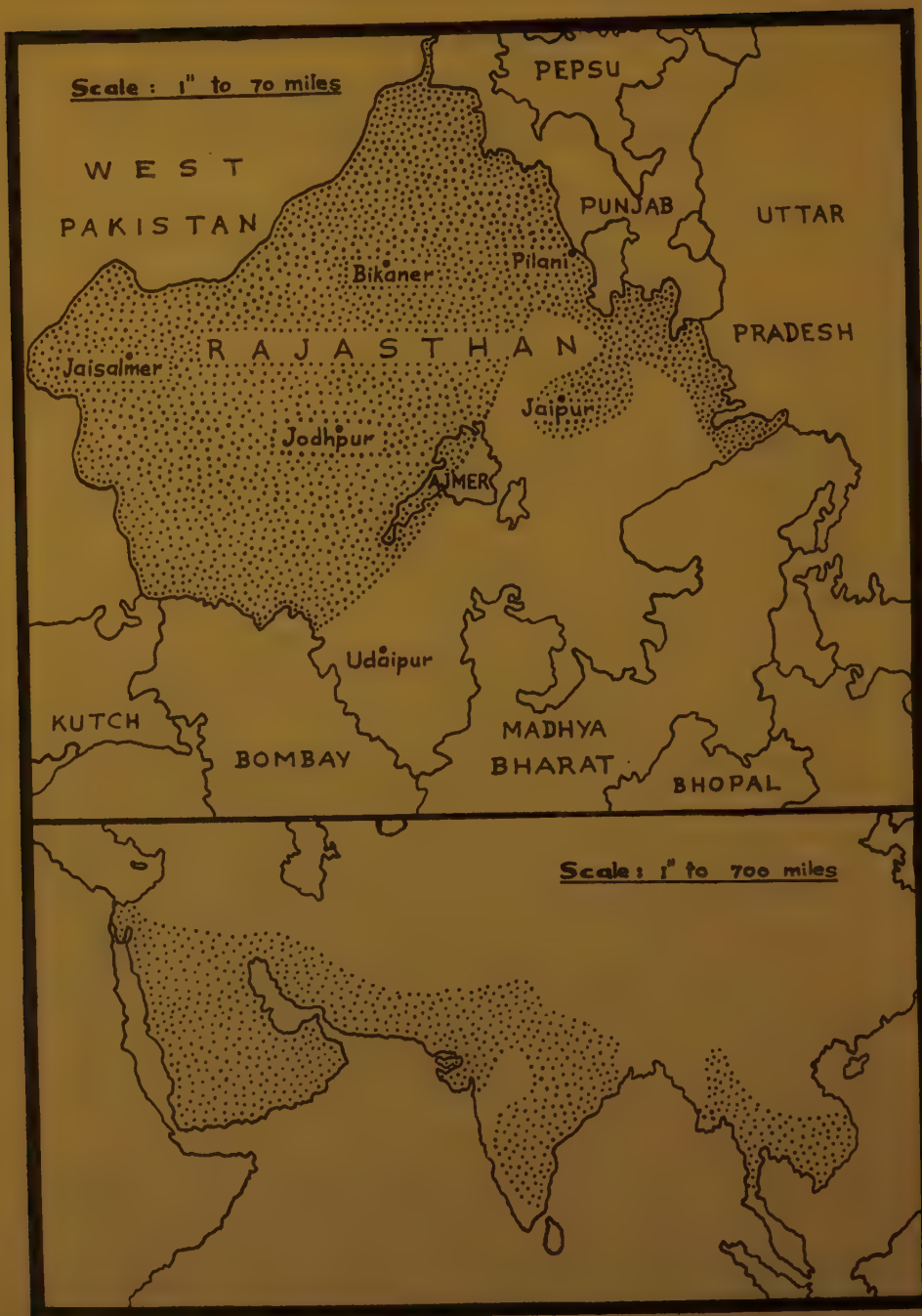


FIG. 1. Geographical distribution of *Mollugo cerviana* in Rajasthan (above) and Asia (below

sand dunes, though occasionally one may come across a few isolated plants growing on other soils. Ratnam and Joshi (1952) have made conflicting statements regarding the habitat of *M. cerviana*. On pages 5 and 6 they report it to be growing *in the shade of the shrub communities* (italics ours). This is contradicted on page 9 where they record it as being found "in open sandy areas." In our intensive field studies, not only in the area investigated by Ratnam and Joshi but also in Pilani as a whole, we rarely came across plants of *M. cerviana* growing in shade. The species almost always grows in the open where it can receive direct sunlight at least for the major part of the day. It is usually met with in pure stands. Occasionally, however, it may be seen in association with the following: *Aerua tomentosa* Forsk., *Bærhaavia diffusa* Linn., *Corchorus tridens* Linn., *Cleome viscosa* Linn., *Euphorbia microphylla* Heyne, *Farsetia jacquemontii* Hook. f. & T., *Gisekia pharnaceoides* Linn., *Gynandropsis gynandra* Merr., *Momordica charantia* Linn., *Mollugo nudicaulis* Lamk., *Portulaca oleracea* Linn. *Spermacoce hispida* Linn., *Tephrosea purpurea* Pers., *Trianthema monogyna* Linn., *T. crystallina* Vahl., *T. pentandra* Linn. and *Tribulus terrestris* Linn.

External Morphology

Mollugo cerviana is an erect, slender and glabrous herb about 3–11 cm. in height (Pl. XII, Fig. 2). There is a normal tap root of a length of about 8 cm. The stems are erect, stiff, glabrous, glaucous and filiform. They are yellowish green and have long internodes. At each node there is a whorl of leaves from which the branches arise umbellately. The leaves may be semi-centric or almost isobilateral. They are fleshy, subsessile, and $1\frac{1}{4}$ to $1\frac{3}{4}$ cm. long.

The long-pedicelled flowers are ebracteate, incomplete, hermaphrodite and actinomorphic. Each flower has five oblong persistent sepals with white membranous margins. Petals are absent. The androecium consists of five stamens and the gynæceum of a pentalocular many seeded ovary. Pollination is entomophyllous (*cf. M. nudicaulis*, Bakshi and Kapil, 1952). The capsules are as long as the sepals and dehisce by longitudinal slits which extend up to two-thirds from the top on all sides. The dispersal of the plant is interesting. As the wind blows, the dry sand is blown along so that the plants lose their hold on the soil. They are finally freed, their branches get entangled with one another, and they roll on the ground, even in presence of slight breeze, scattering the seeds in the process. Another method of dispersal is through the agency of the fruits of *Cenchrus biflorus* Roxb. These have numerous hooked awns possessing immense capacity for animal dispersal. In addition, they are very light and are dispersed by wind also. During the latter process they get entangled with plants of *Mollugo cerviana* and bring about their dispersal through animals.

The species is important medicinally. It is used in fevers, and for promoting lochial discharges and blood purification (Kirtikar and Basu, 1933).

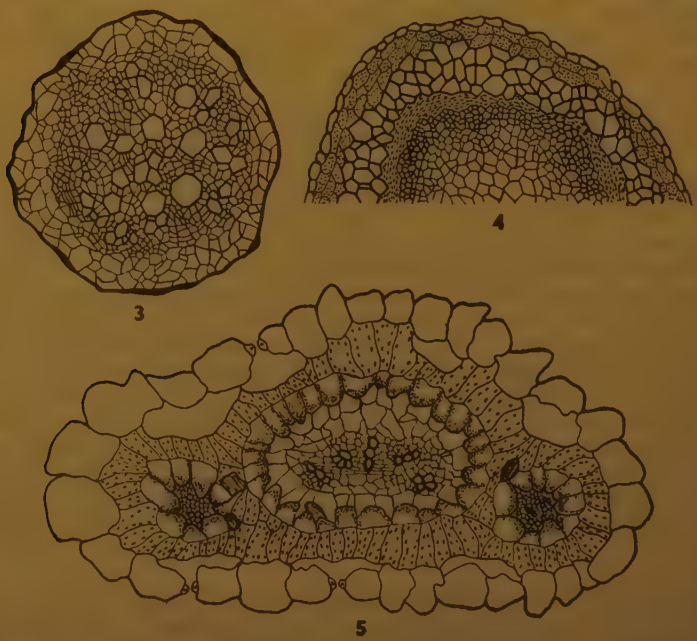
In nature the seedlings of *M. cerviana* appear in the beginning of August after a few light showers. The plant grows in abundance during the next two months. It becomes rare in November and almost disappears in the following month. An interesting fact is its short life of less than 30 days. The plants appear with the first showers, flower within a few days, and disperse the seeds shortly afterwards.

Ecological Anatomy

Root.—The structure is of the typical dicotyledonous type (Fig. 3). The outer walls of epiblema are considerably thick. Anomalous secondary growth, as reported by Metcalfe and Chalk (1950), was not seen in our material.

Stem.—The outer walls of the epidermis are thick (Fig. 4). Hairs and stomata, as seen by Sabnis (1919), are conspicuous by their absence. The cortex is assimilatory and is 2 to 3-layered. Some of the cells contain clustered crystals. A complete ring of endodermis is usually not clearly visible. Pericycle completely surrounds the inner tissues and consists of sclerenchyma. Phlœm and xylem are present in the form of an unbroken ring surrounding the thin-walled pith. Sabnis (1921–24) has reported that there are numerous independent xylem groups abutting into the pith. We could see this arrangement only in *M. nudicaulis* (Bakshi and Kapil, 1952).

Leaf.—The epidermal cells are large and have a coating of wax and cuticle on the outside (Fig. 5). Sabnis (1921–24) reports that in



Figs. 3–5. Transverse sections of root, stem and leaf of *M. cerviana.*

M. cerviana, large cells are intercalated amongst the epidermal cells of ordinary dimensions. This appears to hold good for *M. nudicaulis* (Bakshi and Kapil, 1952). In *M. cerviana* there are hardly any smaller cells. The large cells probably constitute a water storage tissue. Dense stellate hairs have been described by Sabnis (1921–24) in the species. In our material the leaves were glabrous. The stomata are of Ranunculaceous type (*see* Metcalfe and Chalk, 1950) and occur at a slightly lower level than the epidermis. The mesophyll consists of a solitary layer of palisade cells each containing about 3–12 chloroplasts. The only intercellular spaces are a few transpiration cavities. A thick-walled chlorophyllous endodermis is conspicuous. The cells of the pericycle are large and thin-walled. The number of veins in a leaf is usually three. Clustered crystals of calcium oxalate are common.

Seed Output

Size, shape and weight of seeds.—The seeds are minute. In a cross-section they appear almost squarish with blunt corners. The average length and breadth was found to be 0·625 mm. and 0·528 mm. respectively. Their shape as indicated by the Length/Breadth ratio thus works out to 1 : 0·84. The average weight of a seed is 0·0000124 gm. This has been compared with the seed weights of a few other species growing on sandy soil in Table I. It will be seen that the seeds of *M. cerviana* are the lightest in the list.

Table I

Average seed weight in gm. of some species

Species	Habitat	Av. seed wt.	Authority
Anagallis arvensis ..	Dunes and cultivated ground	0·0005510	Dallman (quoted from Salisbury)
Arenaria tenuifolia ..	Sandy fields	0·0000420	Salisbury
Euphorbia portlandica ..	Dunes	0·0016000	Salisbury
Mollugo cerviana ..	Sandy soil and dunes	0·0000124	Present study
Mollugo nudicaulis ..	Sandy soil and cultivated ground	0·0000500	Bakshi and Kapil
Samolus valerandi ..	Sandy places	0·0000220	Salisbury
Trifolium suffocatum ..	Dunes	0·0002370	Salisbury

Seed output.—On the basis of the ecological variations, five localities were selected and an extensive study of the seed output was carried out. As a result it was seen that the soil had a marked effect upon the production of capsules and seeds. The counts for capsule and seed number per plant and seed number per capsule are given in Table II.

In order to study the variation in seed number per capsule in *M. cerviana*, nearly 39,130 capsules were examined under a lens. The process is laborious and speaks for the paucity of similar data

TABLE II

Capsule and seed output

Locality	Plants studied	Total capsules	Av. caps. per plant	Av. seeds per capsule	Av. seeds per plant
Agriculture Farm ..	150	9,780	65	34	2,210
Chandra Bhavan ..	150	5,470	36	32	1,152
Brick Kiln ..	150	5,700	38	30	1,140
Rajput Hostel ..	150	12,140	81	35	2,835
Botanical Garden ..	150	6,040	41	27	1,107

for other species. The counts made are given in Table III. It is seen that nearly 25 per cent. of the capsules, the largest single majority, have 38 seeds in each of them.

TABLE III

Variation in seed number per capsule

No.	No. of seeds	No. of capsules	% of capsules examined
1	24	590	1·15
2	26	3,360	8·59
3	27	340	0·87
4	28	2,380	6·08
5	30	5,490	14·03
6	32	6,260	16·00
7	34	3,750	9·58
8	36	3,310	8·46
9	37	870	2·22
10	38	9,680	24·74
11	40	3,100	7·92

To see if the seed number in a capsule had any relation with the capsule number per plant, a detailed investigation was carried out in the five selected localities. The results were compared with those for *M. nudicaulis* (Bakshi and Kapil, 1952) and were drawn into a graph

(Plate XIII, Fig. 6). It shows that on an average, the seed number increases with an increase in the number of capsules per plant.

It is a familiar fact that the age of a plant affects its reproductive capacity considerably. It has actually been noted for *Lindenbergia polyantha* (Misra and Siva Rao, 1948). A more detailed study was made in the present case by dividing plants of each locality into five successive age classes on the basis of the colour and position of the capsules. Counts were made for capsule number per plant and seed number per capsule. The respective results are given in Tables IV and V. It will be seen that there is a gradual increase in both from the younger plants to the older one.

Germination of Seeds

Seed germination has been variously defined by different authors. Most of the text books call it the "sprouting of seeds" or "resumption of growth by a dormant embryo". A seed is usually considered to have germinated when it produces primary root or shoot or both.

Table IV

Capsule number per plant in successive age classes

No.	Locality	Age class	Minimum	Maximum	Mean
1	Agriculture Farm	1st	3	9	6·0
2	do	2nd	12	23	17·5
3	do	3rd	24	39	31·5
4	do	4th	31	71	52·0
5	do	5th	150	241	195·5
6	Chandra Bhavan	1st	5	9	7·0
7	do	2nd	4	22	13·0
8	do	3rd	22	51	36·5
9	do	4th	33	78	55·5
10	do	5th	62	106	84·0
11	Brick Kiln	1st	3	4	3·5
12	do	2nd	9	26	17·5
13	do	3rd	27	28	27·5
14	do	4th	37	49	42·0
15	do	5th	79	122	100·5
16	Rajput Hostel	1st	9	10	9·5
17	do	2nd	17	34	25·5
18	do	3rd	62	87	74·5
19	do	4th	87	141	104·0
20	do	5th	160	279	219·5
21	Botanical Garden	1st	7	13	10·0
22	do	2nd	11	19	15·0
23	do	3rd	12	80	46·0
24	do	4th	26	57	41·5
25	do	5th	100	122	111·0

Average for age classes
1st .. 7·2
2nd .. 17·7
3rd .. 43·2
4th .. 59·2
5th .. 142·1

TABLE V

Seed number per capsule in successive age classes

No.	Locality	Age class	Minimum	Maximum	Mean
1	Agriculture Farm	1st	28	28	28·0
2	do	2nd	26	34	30·0
3	do	3rd	30	38	34·0
4	do	4th	32	40	36·0
5	do	5th	32	40	36·0
6	Chandra Bhavan	1st	28	30	29·0
7	do	2nd	28	30	29·0
8	do	3rd	28	34	31·0
9	do	4th	28	34	31·0
10	do	5th	30	34	32·0
11	Brick Kiln	1st	24	26	25·0
12	do	2nd	24	32	28·0
13	do	3rd	24	32	28·0
14	do	4th	32	36	34·0
15	do	5th	30	34	32·0
16	Rajput Hostel	1st	30	36	33·0
17	do	2nd	30	36	33·0
18	do	3rd	36	38	37·0
19	do	4th	37	38	37·5
20	do	5th	36	38	37·0
21	Botanical Garden	1st	24	28	26·0
22	do	2nd	24	28	26·0
23	do	3rd	26	28	27·0
24	do	4th	26	28	27·0
25	do	5th	26	30	28·0

Average for age classes : 1st .. .. 28·2
2nd .. .. 29·0
3rd .. .. 31·0
4th .. .. 33·0
5th .. .. 33·0

Mayer (1953) has defined germination as "that group of processes which causes the sudden transformation of the dry seed into the young seedling". Porter (1949) has suggested that a seed shall be considered to have germinated when it has developed those structures that are essential for a normal seedling. Broken seedlings and weak and malformed and obviously abnormal ones shall not be considered to have germinated. We have followed Porter's definition for the study of seed germination. A counted number of seeds were placed in between two pieces of blotting-paper kept moist by a steady supply of water from a capillary arrangement. Experiments were carried out in July 1951, with seeds collected during October–November 1950. After each day's counting the germinated seeds were removed to avoid any possible error.

Effect of light and darkness.—Batches of soaked seeds were placed: (1) Close to a laboratory window through which they received diffused daylight. At night, however, the seeds remained in total darkness. (2) In continuous darkness. (3) In continuous light.

In the first case germination started within 24 hours of soaking and continued for 39 days; in the second the germination was delayed a little and continued for 42 days; and in the last, the germination started within 11 hours of soaking and extended over a period of 19 days only. The percentage of germination was 46, 23 and 17 respectively (Fig. 7). Duration of light, therefore, has a marked effect on germination. This gave an impetus for further investigation in this direction.

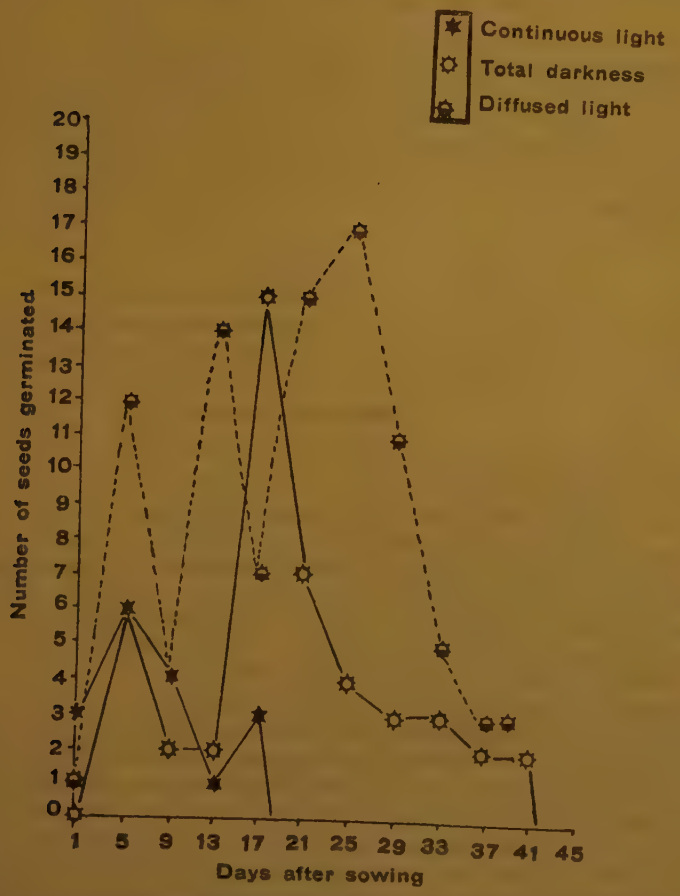


FIG. 7. Graph showing seed germination in *M. cerviana* in continuous light total darkness and diffused daylight.

Consequently, experiments were carried out with 20 sets of seeds, each set consisting of a batch of 100 seeds. One set was kept in light and the remaining 19 in darkness. Each day one of the latter sets was removed to light, and the day to day germination was noted in all the 20 sets. The whole experiment was duplicated and the mean of the two is shown in Fig. 8. It will be seen from the figure that a preliminary period o

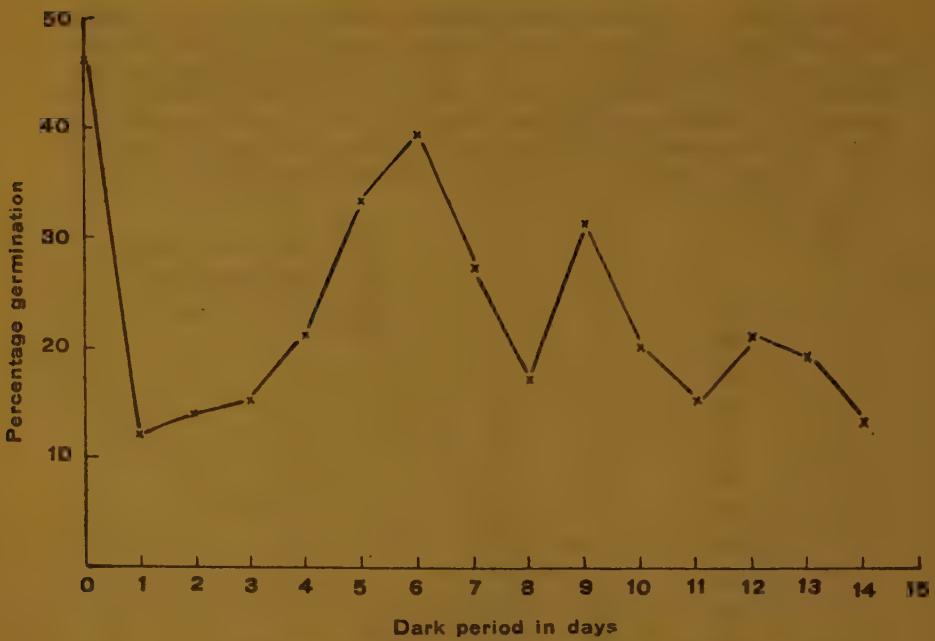


FIG. 8. Graph showing the effect of a preliminary period of darkness on the percentage germination of the seeds of *M. cerviana*.

darkness has a deleterious effect upon germination which decreases with an increase in the dark period. In *Anisochilus eriocephalus* (Bakshi, 1952 *a*), on the other hand, the normal percentage of germination (6·2) first increases with an increase in the preliminary dark period reaching a maximum of 13·4 per cent. for a period of seven days, and then falls sharply almost to zero on the 12th day. Lehmann (1918) has recorded an almost similar case for *Lythrum salicaria*.

Effect of alternate drying and wetting.—Chippindale (*see* Porter, 1949) reports an acceleration in the germination of the seeds of *Dactylis glomerata* when they are exposed to alternate drying and wetting. In *Mollugo cerviana*, on the other hand, the treatment reduced the average percentage of germination to 33.

Effect of atmospheric temperature.—A number of experiments were carried out during August–December 1951, to observe the effect of atmospheric temperature on germination. As a result it was observed that the lower winter temperatures did not favour germination. The maximum percentage (46) was obtained when the maximum and minimum temperatures were 99° F. and 81° F. respectively.

Effect of breaking the seed coats.—Most of the earlier authors (Misra and Shiva Rao, 1948; Bakshi, 1952 *b*) report an increase in germination when the seeds are germinated after breaking their seed coats. A similar treatment for *Mollugo cerviana*, however, decreased the percentage of germination to 11.

Effect of resting period.—Seeds sown soon after collection did not germinate at all. From repeated experiments it was seen that the minimum resting period of the seeds is 5–6 months.

Effect of waterlogging.—The seeds appear to be adversely affected by water-logging. Various experiments indicated that even a slight increase in the water-supply retarded the rate of their germination considerably.

Reproductive and Aggressive Capacity

Mollugo cerviana does not propagate vegetatively. Its average percentage of seed germination is 46. The reproductive capacity of the species, therefore, works out to about 777. A comparison of the reproductive capacity of *M. cerviana* with those of a few other species is made in Table VI from which it is seen that its reproductive capacity is much higher than that of some species like *Anagallis arvensis* or *Mercurialis perennis*. This should warrant a wide geographical distribution of the species.

Table VI

Reproductive capacity of some species

Species	Av. seed output	Av. % germination	Average Rep. cap.	Authority
Anagallis arvensis ..	150	45·0	67	Salisbury
Anisochilus eriocephalus	21,421	6·2	1,328	Bakshi
Digitalis purpurea ..	100,000	100·0	V. high	Salisbury
Lindenbergia polyantha	71,731	98·0	70,266	Misra and Siva Rao
Mercurialis perennis ..	300	5·0	15	Mukerjee
Mollugo cerviana ..	1,689	46·0	777	Authors
M. nudicaulis ..	949	56·0	526	Bakshi and Kapil

Bakshi (1952 *b*) has defined the average aggressive capacity of a species as the product of its average reproductive capacity and the fraction represented by the average percentage survival of its seedlings in nature. The aggressive capacity thus gives an idea of the potentiality of a species to spread and colonize. In *Anisochilus eriocephalus* it has been found to be 127 (Bakshi, 1952 *b*). A similar study could not, however, be made for *Mollugo cerviana* due mainly to the following reasons:—

1. Seedlings of *M. cerviana* cannot easily be differentiated from those of some of its associates.
2. The seedlings match strikingly well with their surroundings. This renders difficult even their spotting.
3. The seeds take hardly a day to germinate; new seedlings therefore keep on appearing every now and then.

However, from the culture experiments it appears that the mortality rate among seedlings is probably very high as even the slightest unfavourable condition may wipe out a whole crop of plants. The aggressive capacity of the species, therefore, seems to be very low.

Ecological Factors Operating upon the Species

Climatic factors.—The climate of Pilani is typical of other arid regions of Rajputana. Rains set in usually in the beginning of July. According to the records in the local Agriculture Farm, Pilani receives an average annual rainfall of about 14 inches. In 1951 it was only 11·47 inches of which 7·84 inches was received in August, about an inch each in June and October, and less than an inch each in May, July and September. The remaining months were almost dry. The rainy days in August are characteristic. There is usually a heavy downpour on two or three occasions, the remaining period experiencing few light showers only. Rain-water is either quickly drained off due to the typical topography or is absorbed by the sandy soil so that after rain the soil surface is usually just moist and not muddy. This seems to be ideal for the germination and growth of *Mollugo cerviana.*

The rainfall and the average minimum and maximum temperatures for the four months during which the species is generally seen in nature, are indicated in Fig. 9.

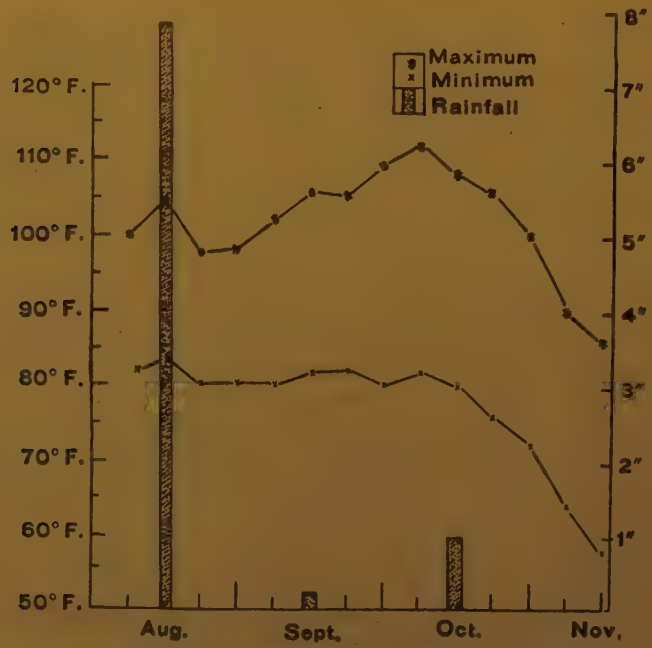


Fig. 9. Graph showing minimum and maximum temperature, and rainfall during August–November 1951, for Pilani.

The species grows in open localities where it can receive direct sunlight almost throughout the day.

Physiographic factors.—The slope of the soil and the height of the dunes which are mostly of the *Barchan* type (*see* Elston, 1953), have a considerable significance for *Mollugo cerviana.* The slope prevents water-logging and the height helps in receiving direct sunlight and in lessening biotic pressure.

Edaphic factors.—The colour of the soil varied in different localities from yellowish-brown to brownish-black. It is usually loose and consists mostly of sand mixed occasionally with a little clay.

The roots of *M. cerviana* are about 8 cm. long. The soil samples were, therefore, collected at the depths of 3, 5·5 and 8 cm. They were brought to the laboratory in cigarette tins and analysed within three hours of collection. For finding out the moisture content, 20 gm. of the sample was dried at a temperature of about 105° C. to constant weight. The percentage of water content was calculated in terms of the dry weight of the soil. From the data (Table VII) it is seen that there is very little moisture in the soil, and except in Agriculture Farm

TABLE VII

Percentage moisture content of soil samples

Date	Locality	Soil samples collected at depths of		
		3 cm.	5·5 cm.	8 cm.
8—8—1951	Agriculture Farm	2·2	2·9	3·0
28—8—1951	do	2·9	3·3	3·5
17—9—1951	do	2·6	3·2	3·4
7—10—1951	do	4·3	5·0	5·0
27—10—1951	do	1·7	2·0	2·3
5—8—1951	Chandra Bhavan	2·5	3·0	3·3
25—8—1951	do	1·2	1·9	2·2
14—9—1951	do	0·9	1·1	1·3
4—10—1951	do	1·1	1·8	2·0
24—10—1951	do	2·0	2·3	3·0
1—8—1951	Brick Kiln	3·3	3·8	3·9
21—8—1951	do	2·3	2·9	2·9
10—9—1951	do	1·2	1·8	2·0
30—9—1951	do	1·1	1·8	1·8
20—10—1951	do	0·8	1·1	1·4
1—8—1951	Rajput Hostel	2·0	2·5	2·8
21—8—1951	do	0·8	1·0	1·1
10—9—1951	do	1·1	1·6	1·8
30—9—1951	do	0·7	1·2	1·3
20—10—1951	do	1·3	1·8	2·0
5—8—1951	Botanical Garden	2·3	2·5	2·5
25—8—1951	do	1·2	1·9	2·2
14—9—1951	do	1·0	1·2	1·2
4—10—1951	do	1·0	1·4	1·7
24—10—1951	do	0·8	1·1	1·8

where by artificial watering the percentage may reach up to 5, it rarely crosses the limit of 3.

The chemical analysis of the soil was done as suggested by Misra (1944). The data are given in Table VIII which show that, though the carbonates and the nitrates are sufficiently represented in the soil, it is generally poor in calcium. The pH value ranges from 7·5–8·5.

TABLE VIII

Chemical analysis of soil samples

No.	Date	Locality	CO_3	NO_3	Ca	pH
1	11—8—1951	Agriculture Farm ..	++	++	++	8·5
2	do	Chandra Bhavan	+	++	+	8·5
3	12—8—1951	Brick Kiln ..	++	++	+	8·0
4	13—8—1951	Rajput Hostel ..	+	++	−	7·5
5	do	Botanical Garden ..	+++	+	+	8·0
6	1—9—1951	Agriculture Farm ..	++	+++	+	8·0
7	do	Chandra Bhavan ..	+	++	++	8·5
8	do	Brick Kiln ..	++	++	+	8·0
9	3—9—1951	Rajput Hostel ..	+	++	−	7·5
10	do	Botanical Garden ..	++	+	+	7·5
11	14–10—1951	Agriculture Farm ..	++	++	−	8·0
12	do	Chandra Bhavan ..	++	++	++	8·5
13	15–10—1951	Brick Kiln ..	+	++	−	8·5
14	do	Rajput Hostel ..	+	++	+	8·0
15	do	Botanical Garden ..	+++	+	+	8·0

N.B.—Although chemical analysis for numerous samples was carried out, only the averages for each day's collections from a locality are given above.

Biotic factors.—Mollugo cerviana avoids thickly populated spots and grows extremely well in places where no other plants appear. The outstanding example of this is seen on the sand dunes which, save for the growth of *M. cerviana*, are almost barren. Safeeulla and Thirumalachar (1951) have reported *Cystopus molluginicola* on *Mollugo cerviana*. In Pilani the fungus does not appear on the plants. Grazing animals, especially goats and sheep, have a special liking for the species. Man is also an important biotic factor since the plants are of considerable medicinal value.

Culture Experiments

The following sets of culture experiments were carried out in order to see the effect, if any, of the nature of substratum, interspecific competition and water-logging on the germination and growth of *M. cerviana.*

Seeds were sown in six pots numbered I–VI containing "natural" soil (on which the species abounds in nature), garden soil, black cotton soil, loam, soil from the brick kiln and calcium-rich soil respectively. Fifty seeds were sown in each of the six pots which were kept in an open enclosure in the Botanical Garden. They were moderately watered once a day and were observed daily for about a fortnight. Strangely enough not a single seedling appeared in any of them. This seems to be due probably to one or both of the following reasons:—

1. Rains which were quite frequent during the fortnight, probably caused water-logging.
2. The seeds, being very minute, were washed deep down into the soil during the watering of pots.

The experiments were repeated with all the possible precautions and the pots were now kept on the window sill of the botanical laboratories where they received diffused daylight, and were saved from climatic disturbances. The observations were made daily. It was seen that seedlings appeared in pots I and V within two days of sowing. In pots II, III and IV the process was delayed by two to four days. In pot VI there was no germination at all. Seedlings growing on "natural" soil were the healthiest and those on black cotton soil the most stunted. On loam the seedlings were quite healthy though their growth was not as vigorous as that of plants in pot I which contained "natural" soil. The relative growth in cm. of plants growing in various pots has been shown in Fig. 10.

Seeds were sown in two pots marked I and I A both containing "natural" soil. Weeding was done only in the former. Observations were made at regular intervals and it was seen that in I A the plants showed extremely stunted growth. *Mollugo cerviana*, therefore, cannot stand interspecific competition.

Similar experiments were conducted to note the effect of water-logging on the germination and growth of the species and it was seen that it could not survive in water-logged soils, even in a stunted form, for more than a couple of days.

In the plants growing in different pots no change in the morphological characters of *Mollugo cerviana* was observed. The species has clearcut features which were maintained in every case.

Discussion

The seeds of *Mollugo cerviana* are very minute and light. The species is, therefore, handicapped by the small amount of reserve food available for the seedlings until they themselves are able to photosynthesize. This explains its occurrence in excluded and isolated localities. Its capacity to colonize in the face of competition thus

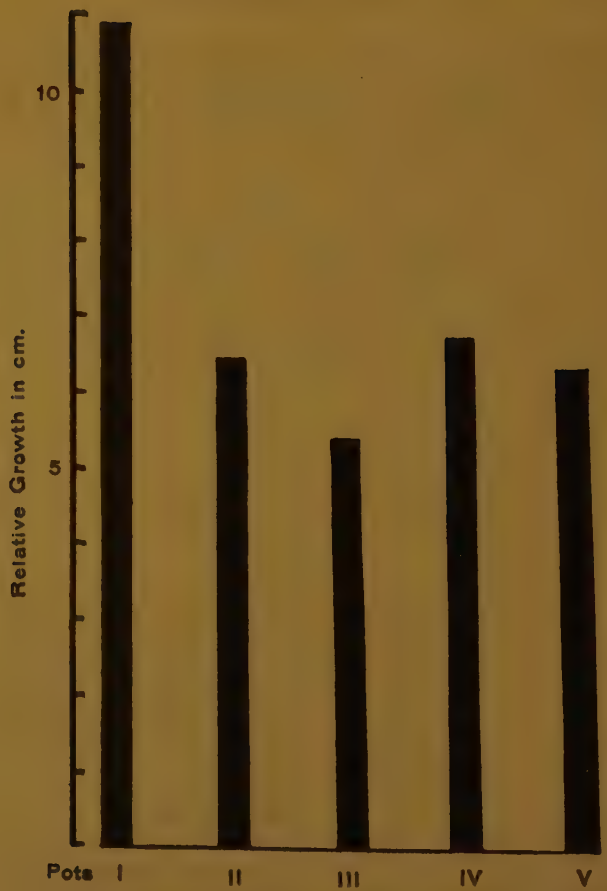


FIG. 10. Relative growth in cm. of plants grown in pots I–V in culture experiments.

appears to be limited by the amount of food reserve that the seed contains. Salisbury (1942) has arrived at similar conclusion for some British species.

The capsule and seed output per plant varies considerably in different localities. On an average a plant produces about 52 capsules and 1,689 seeds. The seeds per capsule increase in number with the increase in capsules per plant. The seeds and the capsules show a gradual increase from the younger to the older plants. In contrast to this is the case of *Lychnis githago* (Salisbury, 1942) where ageing results in a corresponding decrease in seed output. Salisbury has attributed this to an "internal competition factor". The absence of such a factor in *Mollugo cerviana* may be accounted for by its very short life.

It appears that the species needs a large seed output for its survival. It has to face varied unfavourable conditions and hence probably there has been brought about a "nicety of adjustment between the seed output and mortality". From this Salisbury (1942) concludes that the potential reproductive capacity of a species is a measure of its susceptibility to mortality and that such a relation, if it could be established, would at once place the numerical values representing the reproductive capacity of species in the front rank of biological data.

As suggested by Stiles (1950) and Bakshi (1952 *a*, *b*) the seed germination was studied in relation to several factors. The seeds require a resting period of about five to six months, and minimum and maximum temperature of about 81° F. and 91° F. respectively. In diffused daylight the average percentage of germination is 46. In continuous darkness and continuous light the percentage declined to 23 and 17 respectively. Continuous light, is therefore, more harmful to germination than continuous darkness. Unlike the seeds of *Anisochilus eriocephalus* (Bakshi, 1952 *a*, *b*) and *Lythrum salicaria* (Lehmann, 1918), those of *Mollugo cerviana* are adversely affected by a preliminary period of continued darkness. Here the germination never increases above the normal. Alternate drying and wetting and breaking of the seed coats have a deleterious effect on germination.

The reproductive capacity of the species has been found to be 777. This is considerably high when compared to species like *Anagallis arvensis* (Salisbury, 1942) and *Mercurialis perennis* (Mukerjee, 1936), and may be accounted for by its greater seed output and higher percentage of germination.

Notwithstanding these favourable factors of quantitative biology, the ecological and geographical distribution of *Mollugo cerviana* is limited.

M. cerviana is very sensitive to the moisture of the substratum. Water-logging is extremely injurious during both germination and growth. A characteristic feature of its habitat is its loose nature. The sandy and slopy soil provides it with not only well aerated substratum but also drier conditions which the plant badly needs. Its incidence in nature does not appear to be controlled by any special salt requirements. The plant is, however considerably susceptible to biotic disturbances. The species is not aggressive and is easily weeded out by others. The favourable features with respect to these factors are obtainable on sand dunes and sandy soil. The ecological distribution of the plant is, therefore, narrow.

The weather conditions in Pilani are unusually uncertain. The rainy season is characterised by heavy downpour on just a few occasions with light showers in between. Occasionally there may be intervening long periods of drought. The plant seems to have adapted to these conditions well—its life-cycle is short, its reproductive capacity considerably high, its water and salt requirements few, and its capacity to compete little. These factors coupled with its non-aggressive nature and the requirements of a special habitat have restricted the area of

its distribution to the drier and warmer regions of Asia, Africa and Australia. The barriers are thus both ecological and geographical. In this respect it closely resembles *Lindenbergia polyantha* (Misra and Siva Rao, 1948) and *Anisochilus eriocephalus* (Bakshi, 1952 *b*). It, however, differs from them in not forming any ecotypes. The species has, therefore, been founded on distinct and good characters incapable of showing variations under the influence of environment.

As stated earlier, *Mollugo cerviana* grows on sandy soil and sand dunes where it is exposed to direct sunlight, and winds and storms of considerable velocity. The amount of water in the soil is usually less than 3 per cent. of its dry weight and the humidity of the atmosphere almost negligible. These factors constitute a typical xerophytic environment which has considerably modified the morphological features of the plant. The paucity of water has resulted in the thick outer walls of the epidermis, the presence of cuticle and wax, and the occurrence of stomata below the epidermal level. The stomata are few in number on the leaves and completely absent on the stems. This helps in checking transpiration. Water loss is further checked by a considerable reduction in the exposed surface area of the plant and by the rolling of the leaves. The presence of water storage cells in the leaf epidermis is accounted for by the almost negligible water content of the soil. Sabnis (1921–24) has reported that the thinness of the outer epidermal walls in *M. cerviana* is compensated by the presence of dense stellate hairs. In our material, however, the leaves were perfectly glabrous. It is perhaps the "stellate hairs" which seem to have been compensated by the presence of thick cuticle and waxy coating.

The effect of strong winds has been the development of the solid core of xylem and sclerenchyma in roots, the concentric rings of thickened pericycle and xylem in stems, and the occupation of the greater part of leaves by veins.

High light intensity and internal resistance to flow resulting from water deficit apparently contributes to the development of palisade tissue (Shields, 1950). This appears to be true for *M. cerviana* where palisade, under high light intensity and greater water loss, has developed at the expense of spongy tissue.

In conclusion, it may be said that the characteristically xeric environment has resulted in the development of typical xerophytic characters in *M. cerviana*. According to the classification of Weaver and Clements (1938) it may be said to be both "Drought Evading" and "Drought Escaping". This dual nature appears to be due to the adverse environment which it has to face even during its comparatively short life.

Summary

The present work deals with the morphology and ecology of *Mollugo cerviana* Ser. which grows abundantly in and around Pilani (Rajasthan).

In nature the seedlings appear in August. They flower after a brief period of vegetative growth. Mature seeds are obtainable from

FIG. 2

T. S. Bakshi and R. N. Kapil

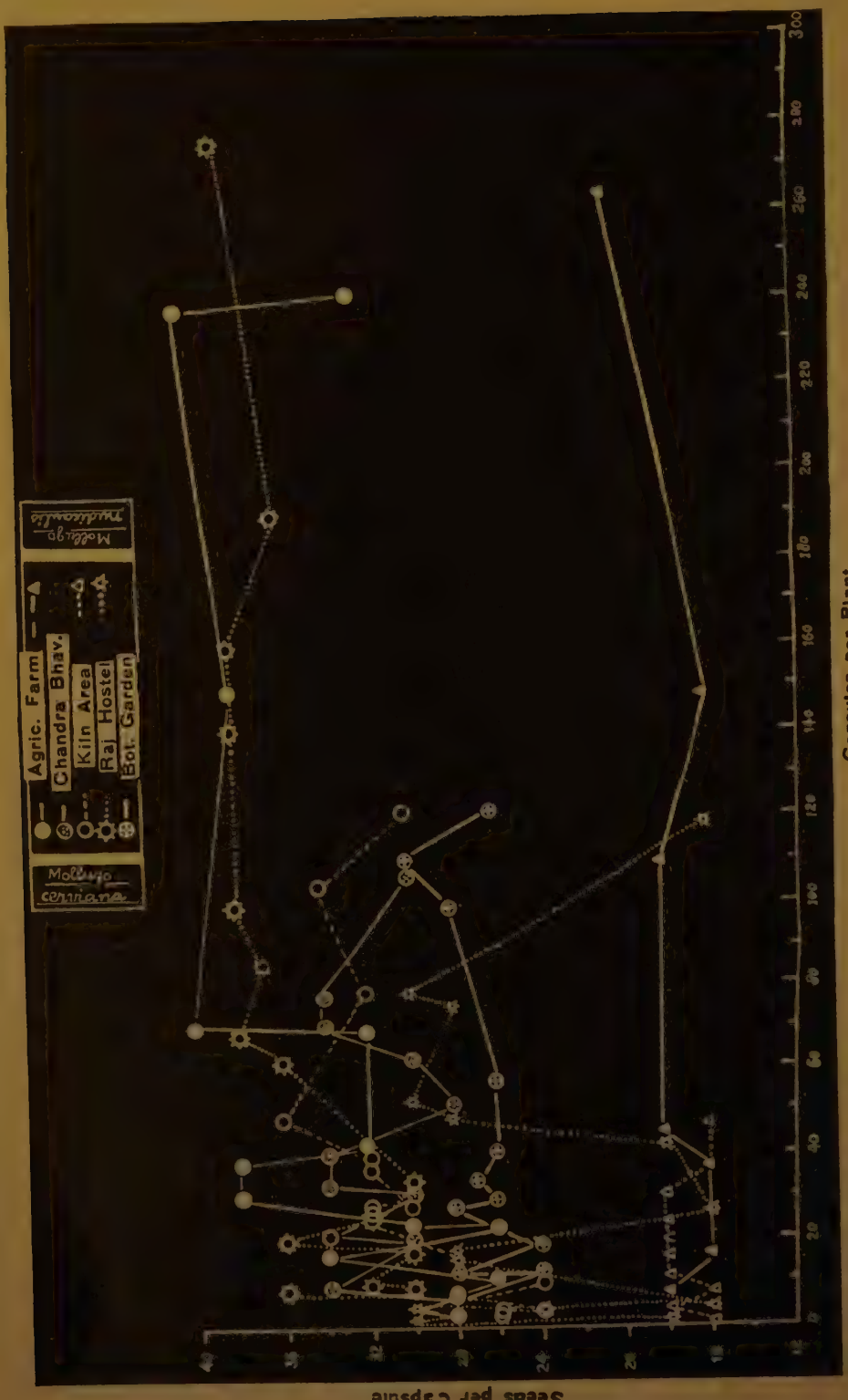


FIG. 6

T. S. Bakshi and R. N. Kapil

September onwards. They are minute and are easily disseminated by wind.

The average capsule and seed output per plant is 52 and 1,689 respectively. The seed number per capsule and capsule number per plant increase with the age of the plant.

The average percentage of germination is 46 which decreases to 23 in total darkness and to 17 in continuous light. Low temperature, water-logging, breaking of seed coats, alternate drying and wetting, and a preliminary period of continued darkness have a deleterious effect on germination. The reproductive capacity has been found to be 777.

The environmental factors operating upon the species have been described. It appears that the incidence of the species is directly related to sunlight. Its abundance on sandy soil and sand dunes is alluded to a specific soil and few biotic disturbances. Culture experiments were performed. These confirmed the field observations.

The species shows xerophytic characters. It does not form any ecotypes, and its distribution appears to be limited by ecological and geographical barriers.

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SOIL CONDITIONS AND ROOT DISEASES

XIII. Symptomatology of *Fusarium* Wilt*

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Introduction

Symptomatology is of great value in diagnosis in all branches of pathology. Although there are many previous reports of disease symptoms in plants affected by wilt producing fungi, the first detailed report of symptom production in aerial parts of plants infected by soil-borne fungi causing vascular wilts, appears to be that of Wellman (1941) who described epinasty in tomato wilt as the earliest symptom, of Foster (1946) who described 'vein clearing' in tomato infected by *Fusarium lycopersici* and of Satyanarayana and Kalyanasundaram (1952) in cotton wilt caused by *Fusarium vasinfectum.*

The following critical and detailed observations on symptomatology were made on cotton plants infected by *Fusarium vasinfectum*, as they are considered to be of fundamental importance in early diagnosis of vascular Fusarial wilts and in understanding the nature of the disease. Despite the fact that the primary infection foci of *Fusarium vasinfectum* on cotton plants are restricted to the roots, the symptoms are largely manifest on the aerial parts of plants. As the symptom here is similar to a systemic infection by virus, histo-chemical studies of wilted plants as also starch tests were conducted to understand the nature and path of toxic action prior to appearance of visual toxæmic symptoms.

Materials and Methods

The general laboratory technique followed was as proposed by Rawlins (1933), for preparation of media, inoculation, maintenance of cultures, etc.

Culture of *Fusarium vasinfectum* Atk. supplied by Centraalbureau voor Schimmelcultures (Baarn) was used to infect two strains of cotton (*Gossypium arboreum*) Karunganni (K. 2) and Malvi (M. 9) both susceptible to the wilt, in the course of these experiments.

Soil used and Artificial infection.—Air-dried and sieved (mesh 1/18″ square) garden soil in glazed or earthenware pots were used. For all experiments of artificial infection of the plants with the pathogen, the soil was sterilised at 20 lb. steam pressure for two hours.

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* Part of a Thesis approved for the Degree of Doctor of Philosophy of the University of Madras, 1953.

The pathogen grown in oat-soil (soil: oats: water: : 9 : 1 : 3; autoclaved at 20 lb. steam pressure for two hours) for 21 days was mixed with weighed amounts of sterilized soil and after 48 hours of incubation, the required number of seeds were sown. In all cases initial moisture level of the soil was adjusted at 50% level and after germination the requisite amount of water was supplied to avoid physiological wilting.

All the experiments were conducted in the green-houses where the maximum temperature varied from 28–34° C. during the year.

Experimental

Symptomatology

In plants that were infected by the pathogen, it was very common to see the 'vein clearing' symptom, before the actual wilting of plants, caused by the yellowing of those regions of leaves closely aligning the veins and veinlets. However, it was not uncommon to see certain plants wilt without any 'vein clearing' symptom. In such cases it was observed that the stems of these plants were damaged first and the leaves withered as a consequence. By far the great majority of plants showed the above early symptom of 'vein clearing' before wilting.

Different types of 'vein clearing'.—(*a*) The most common type was the yellowing of tissues around all the major veins and veinlets of the leaves simultaneously (Plate XIV, Fig. 1) which slowly intensified into the necrosis of the interveinal tissues and the death of the leaves (Plate XIV, Fig. 2).

(*b*) In the second type observed yellowing started around all the major veins and few adjoining veinlets (Plate XIV, Fig. 3) and this yellowing intensified. The leaves were seen to be cut off from the petiole and to wither even before interveinal necrosis started. Many of the veinlets in the peripheral region of the leaves were not at all affected even at this late stage (Plate XIV, Fig. 4).

(*c*) The development of partial 'vein clearing' of leaves was also observed at times. The veins and veinlets of only one half of the leaves showed the symptom (Plate XIV, Fig. 5) to start with and the healthy looking half developed symptom when the other half had reached the advanced stage of necrosis (Plate XIV, Fig. 6).

Symptom production with reference to age of the host.—When plants were infected at different age levels, observations were made on the relationship between symptom production and age of the host. The results are presented in Table I. It will be seen from the table that, with increase in age of the host at the time of infection, the time taken for the spread of the symptom and complete death also increased.

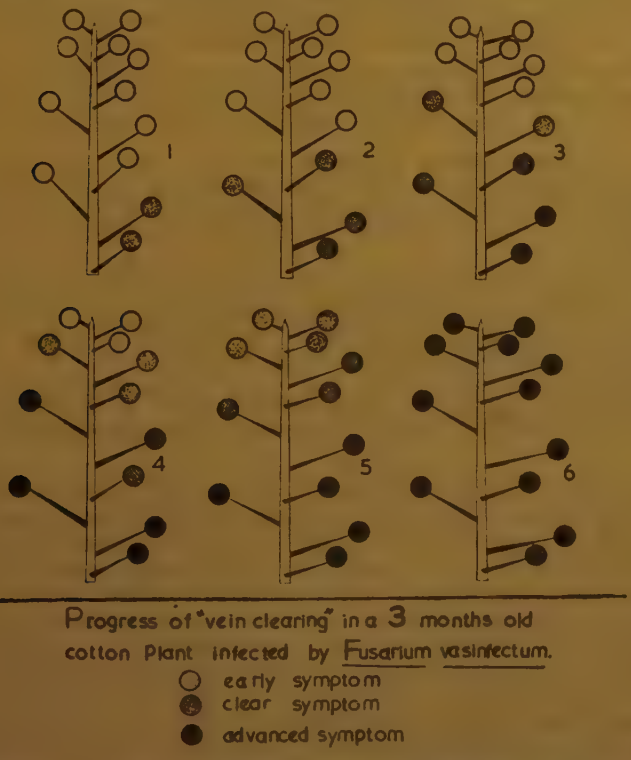
Progress of Symptom in an infected cotton plant.—The progress of 'vein clearing' symptom in a cotton plant, 90 day old and infected by *Fusarium vasinfectum* is described below. A diagrammatic representation of the same is given in Text Figs. 1–6.

TABLE I

Table showing the minimum and maximum time intervals observed from the early disease symptom to complete death, of hosts inoculated at different age levels

No. of days after inoculation	Inoculated 1 Minimum (hours)	Inoculated 1 Maximum (hours)	Inoculated 2 Minimum (hours)	Inoculated 2 Maximum (hours)	Inoculated 3 Minimum (hours)	Inoculated 3 Maximum (hours)	Inoculated 4 Minimum (hours)	Inoculated 4 Maximum (hours)
10	12	36	24	36	32	96	72	124
30	48	72	48	120	48	160	94	160
60	96	144	108	168	98	198	144	260

Inoculated 1: Germinated in inoculated soil.
Inoculated 2: Inoculated at the age of 10 days.
Inoculated 3: Inoculated at the age of 20 days.
Inoculated 4: Inoculated at the age of 30 days.



TEXT-FIGS. 1–6. Fig. 1 shows initial symptom as first observed; Fig. 2 shows wilt progress after 2 days; Fig. 3, after 4 days; Fig. 4, after 6 days; Fig. 5, after 8 days; and Fig. 6, after 12 days.

The symptoms were seen to develop in acropetal succession from the lowest leaf to the youngest leaf and the whole process from the initial symptom appearance to complete death took 12 days. Though this was the common type of progression of 'vein clearing' observed, sometimes leaf 4, developed the symptom after leaf 1. Then the other leaves 2 and 3 developed the symptom which progressed upwards. A close scrutiny revealed that leaves 1 and 4 were in the same orthostichy.

Histochemical Analysis of Diseased Plants

Sections of fresh leaves showing 'vein clearing' when observed for anatomical details, revealed zones of yellow tissues around vascular bundles alternating with dark green areas. The yellow zones consisted of large number of palisade and mesophyll cells which contained disintegrating chloroplastids.

Microtome sections of leaves showing 'vein clearing' and healthy ones were prepared following the standard technique of Johansen (1940) and were stained with Hæmotoxylin. Photomicrographs of the sections are presented in Plate XIV, Figs. 13–16.

The following features are noteworthy.

(1) The cells of the palisade layer in the diseased leaf appear elongated and the cell walls appear shrivelled (Plate XIV, Fig. 13) compared to normal healthy cells of the healthy leaf (Plate XIV, Fig. 14).

(2) The cells of the palisade layer have a profuse distribution of chloroplastids in the healthy leaf (Plate XIV, Fig. 14) while the diseased leaf the fewer and not very healthy chloroplastids (Plate XIV, Fig. 13).

(3) The general cytoplasm of the healthy palisade cells is uniformly and darkly stained (Plate XIV, Figs. 14 and 16). However, in the diseased leaf the cytoplasm is not darkly stained (Plate XIV, Figs. 13 and 15) and has certain granular inclusions.

(4) The cell walls of the mesophyll layers of the diseased leaf also show slow disintegration and more so the chloroplastids inside them.

Chlorophyll content of diseased and healthy leaves.—Quantitative estimation of total chlorophyll and also the individual components—chlorophyll '*a*' and '*b*'—were made following the method of Comar and Zscheile (1942). All quantitative estimations were made with ether solution of chlorophyll and readings were taken in the Beckman Absorption Spectrophotometer for the various wavelengths from 4,000–6,800 Å. Following the method of Comar and Zscheile (1942), the amount of chlorophyll could be calculated with the help of absorption values at 6,600Å and 6,425 Å. The absorption values at other wavelengths were used to check the correctness of values obtained. The results are presented in Table II. The quantity of total chlorophyll as well as the individual components in the diseased leaves were lower than in apparently healthy and healthy leaves.

TABLE II

The Relative Plastid pigments content of healthy and Fusarium vasinfectum *infected cotton plant leaves*

Pigments	Healthy	Diseased	Disease escape or apparently healthy
Total Chlorophyll ..	100	78	119
The Chlorophyll content of healthy and Fusarium vasinfectum *infected plant leaves Mg. per litre*			
Total Chlorophyll ..	9·40	7·40	11·20
Chlorophyll A. ..	6·00	4·80	8·20
Chlorophyll B. ..	3·40	2·60	3·00

Starch Test as a Diagnostic Method of Early Symptom of Fusarial Wilt

The leaves of diseased plants were subjected to two types of starch tests. In one, the leaves were plucked from the plants late in the evening after a light period and tested for starch. In the other, the plants were kept overnight in dark allowing for translocation of synthesised starch and leaves were tested early in the morning.

Preliminary experiments with the leaves indicated lack of starch along the regions of 'vein clearing' after a light period (Plate XIV, Fig. 7) discontinuous patches of black regions along the major veins and disappearance of starch from most of the other regions when tested after a dark period (Plate XIV, Fig. 8). The leaves from healthy plants gave a dark blue colour when tested after a light period and less intensely when tested after a dark period.

As the starch test after a light period gave a positive and clear picture of the disease symptom, this experiment was extended to leaves showing different stages of 'vein clearing,' incipient symptoms and growing in infected soil with no symptoms.

When leaves of plants showing no visual symptom but growing in *Fusarium vasinfectum* infected soil—the sections of the roots of these plants showed the presence of the fungus inside the vascular elements —were subjected to the first type of starch test, they stained black except for streaks of few white lines.

Leaves showing partial 'vein clearing' were tested for starch next. The regions of 'vein clearing' gave a clearer picture of starch inhibition. In addition to this the other veins and veinlets of the leaves also showed starch inhibition (shown by an arrow in Fig. 9 of Plate XIV) though no visual 'vein clearing' symptom was seen along these regions before the test.

The line of inh bition of starch synthesis in these cases probably represented the very early symptom of toxin action not apparent in

the leaves before the test and which might have developed in due course as 'vein clearing' symptom.

In the advanced stage when the necrosis of the interveinal tissues had also started the whole leaf stained white with practically no starch (Plate XIV, Fig. 10).

The leaves showing different stages of symptom when tested for starch after a dark period, indicated disappearance of starch from certain areas and accumulation along certain veins (Plate XIV, Figs. 11 and 12).

Toxin movement in a three month old cotton plant shown by starch test.—Three month old cotton plants developing early symptoms of disease as indicated by the 'vein clearing' in the basal two leaves were selected and starch test applied to all the leaves. The healthy plants in the uninfected soil formed the control.

There was marked inhibition of starch synthesis in leaves 1 to 5 of infected plants along certain regions. Leaves 1, 2 and 4 had the least amount of starch compared to leaves 3 and 5. The absence of starch in leaves 3 to 5 without any visual disease symptom, unlike in leaves 1 and 2 which showed the 'vein clearing' symptom, could be explained only on the basis that inhibition of starch preceded the visible 'vein clearing' symptom as early as 48 hours (Refer Text-Fig. 1).

Discussion

The 'vein clearing' symptom seen on the leaves of *Fusarium vasinfectum* infected cotton plants (Plate XIV, Figs. 1–6) was the earliest symptom of wilting seen by the unaided eye and seems to simulate some of the virus infections as Potato Virus Y on *Nicotiana tabacum* var. white burley, Hyoscyamus III disease of tobacco, etc. The only other report of similar symptom caused by any other species of Fusaria is that of Foster (1946) in the case of tomato wilt caused by *Fusarium lycopersici*. Recently it was shown by Gäumann (1952) that this symptom picture could be produced by Fusaric acid—Fusaric acid causes 'vein clearing' at lower concentrations and stem necrosis at higher concentrations—one of the toxins of *Fusarium vasinfectum* and *Fusarium lycopersici*. In this context it is worthwhile recalling the observations of Bawden (1943) that the symptoms of virus diseases are often more closely simulated by the action of toxic substances and root damage than those caused by other pathogens.

The different symptomatological pictures described here (Plate XIV, Figs. 1 to 6) have been produced by different concentrations of the toxins *in vitro* (Gäumann, 1952; Kalyanasundaram, 1953) and these *in vivo* reactions largely bear out toxæmia of differing severity. The partial 'vein clearing' observed on the leaves of infected plants (Plate XIV, Figs. 5 and 6) is of great importance in the light of Bawden's observations (1943) that in cases of toxic symptoms a continuous supply of toxin if interrupted can bring the plants to normal conditions, unlike in virus infections. It may be also a case of localised toxæmia which we could envisage in the light of known cases of host resistance brought

about by naturally synthesised antidote to Fusarial toxins (Wolley, 1946).

The results of experiments dealing with age of the host and disease infection (Table I) indicated, that by increasing the age of the host at the time of infection, the progression of 'vein clearing' and consequently the severity of disease could be retarded. By referring to the age of the plant, only the aspect of increased fresh weight of the plant and the consequent increase in absolute synthesising capacity (Kalyanasundaram, 1953) must be taken into consideration as opposed to plants of younger ages, as these are the factors that mainly affect the reactions of the toxins (Gäumann, 1951).

The progression of 'vein clearing' in a cotton plant (Text-Fig. 1) seems to indicate the probable path of toxin movement inside the vascular strands of the infected plants. When antibiotics produced by fungi in soils have been demonstrated to be taken by plant vascular system (Brian *et al.*, 1951), it is all the more reasonable to imagine systemic movement of toxins produced inside the vascular system. The symptoms were seen to develop on the leaves in acropetal succession, although there are certain variations from this type. Even in cases of apparently irregular progression of symptom, there was some regularity in that the leaves in the same orthostichies developed the symptom before the other leaves on the axis.

The histochemical study of diseased leaves showed (Plate XIV, Figs. 13–16) elongation and disintegration of cells in the chlorenchymatous tissue aligning the vascular bundles, fewer chloroplastids, and dechlorophyllation of healthy plastids. A quantitative estimation of total chlorophyll as well as the individual components indicated reduced amounts in the diseased leaves (Table II). As leaves of similar age and size were taken for estimation and as the average area of 'vein clearing' formed about a third portion of the total leaf area,t he quantity of pigments in the diseased leaf was also reduced by about the same proportion.

Starch tests have been used in the case of virus diseases to trace the path of systemic infections (Holmes, 1931, 1932; Smith, 1934). Starch test as a diagnostic method to show the path of toxin movement—as shown by inhibition of starch synthesis, after a light period along certain regions of leaves of infected plants, which in due course developed the early visual 'vein clearing' symptom (indicated by an arrow in Plate XIV, Fig. 9)—well in advance of the visual symptoms seen by the unaided eye *is* reported here for the first time in a Fusariose disease. The point of interest and importance in comparing the early symptoms of vascular wilts and virus infections is that, in both cases, there is inhibition of starch synthesis along the path of invasion—virus invasion in one and toxin(s) invasion in the other. However, in *Fusarium vasinfectum* infection of cotton, unlike in majority of systemic virus infections, there is probably no inhibition of translocation of synthesised food materials, as is evident from the disappearance of starch from most of the synthesised areas (Plate XIV, Figs. 8, 11 and 12) in the early stages of disease. In the advanced stage of disease when

the stem and petiole get necrosed and normal photosynthetic activity of the leaf ceases (Plate XIV, Fig. 10) there is no more translocation.

Applying starch test to 90-day old cotton plants showing the visual symptom in the lowest two leaves, it was possible to show that inhibition of starch synthesis started even as early as 48 hours prior to the appearance of visual symptom in the other younger leaves, confirmed later by carbohydrate estimations of the author (Kalyanasundaram, 1953). The point for consideration, as affecting the host, that comes out of these results, is that those areas of the leaves not affected by toxin(s) continue their normal photosynthetic activity (Plate XIV, Figs. 7 and 9) until they are also affected by the lethal concentrations of the toxin(s) in due course (Plate XIV, Fig. 10). Thus, in the early stage of *Fusarium* infected plants the upward transport of inorganic salts as shown by Waggoner and Dimond (1952) as well as the downward transport of synthesised food materials, as indicated by starch test here, were not considerably affected.

Summary

A complete study of symptomatology of cotton plants infected by *Fusarium vasinfectum* was made. The 'vein clearing' on the leaves caused by this causal agent was the earliest visual symptom. Three major types of 'vein clearing' observed have been described with a reference to symptomatological similarity between certain virus infections and this root-infecting pathogen. The progression of 'vein clearing' in a three month old cotton plant is described with a diagrammatic representation.

The anatomy of leaves showing 'vein clearing' indicated that the chlorenchyma aligning the vascular bundles were affected, especially the plastids inside them. The chlorophyll content of the diseased leaves was lower than that of healthy plants as well as the disease escaped plants.

Leaves from infected plants indicated inhibition of starch synthesis along the regions of 'vein clearing' when tested for starch after a light period. When tested, however, after a dark period starch translocation was indicated in the earlier stages of the disease. It was possible by this starch test (conducted after a light period) to indicate the path of toxin(s) movement much in advance of the visible symptom. Starch test as a diagnostic method of early wilt symptoms in plants infected by *Fusarium vasinfectum* is reported here for the first time.

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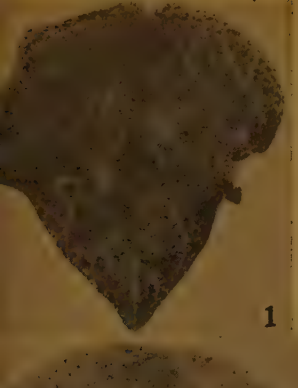
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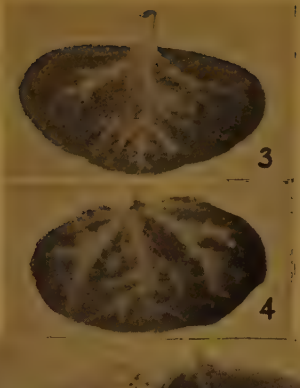
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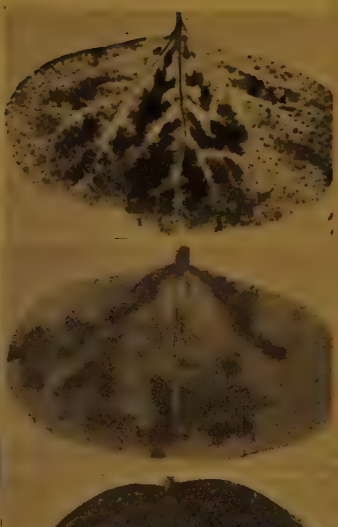

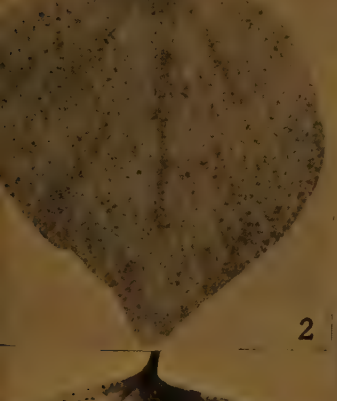
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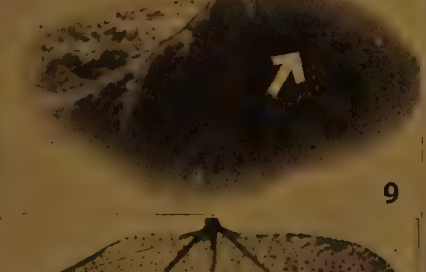
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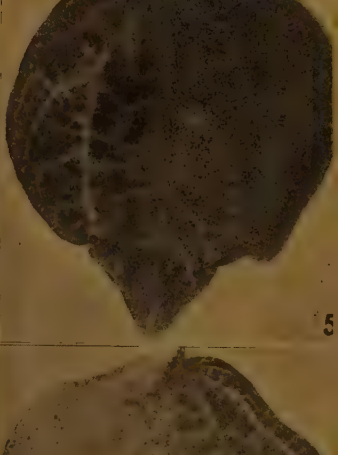
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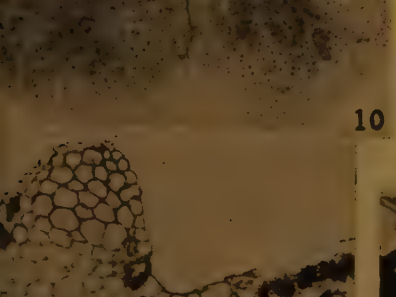
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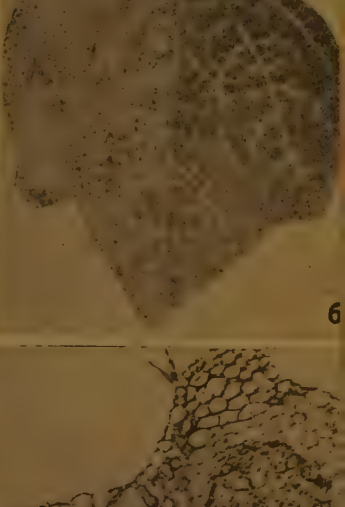
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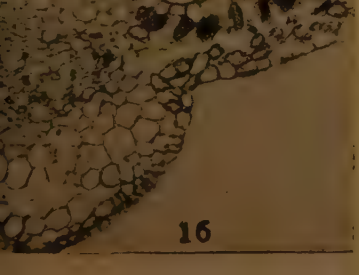
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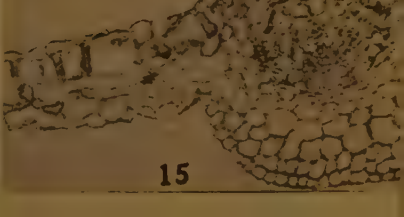
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Explanation of Plate

Figs. 1-6. Different stages of ' vein clearing ' seen in cotyledonary and ordinary leaves of cotton plants. Figs. 7–12. Starch pattern exhibited by leaves showing ' vein clearing'. Figs. 13–16. Transverse section of diseased and healthy leaves of cotton plants. Figs. 13 and 14, ×280. Figs. 15 and 16, ×120.

A SYSTEMATIC ACCOUNT OF THE DIATOMS OF BOMBAY AND SALSETTE

PART III*

Pennales: Sub-orders—Biraphidineæ (*Contd.*)

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(Received for publication on July 20, 1954)

IV. Sub-order BIRAPHIDINEÆ

(1) *Family* NAVICULACEÆ

Sub-family Naviculoideæ

Genus *Navicula* Bory, 1822

Section *Naviculæ orthostichæ* Cleve

104. *Navicula cuspidata* Kütz.

(Fig. 105)

Van Heurck, *Treatise on the Diatomaceæ* (Trans. by W. Baxter), 1896, p. 214, pl. 4, fig. 190; Hustedt, Fr., Pascher's *Süsswasser-Flora*, Heft 10, 1930, p. 268, fig. 433; Skvortzow, B. W., Diatoms from Kizaki Lake, Honshu Island, Nippon, *Philip. J. Sci.*, Vol. 61, 1936, p. 33, pl. 6, fig. 16; Diatoms from Ikeda-Lake, Satsuma Province, Kiewsien Island, Nippon, *ibid.*, Vol. 62, 1937, p. 200, pl. 4, fig. 9.

Valves rhombic-lanceolate with acutely rounded ends. Raphe thin, straight, with hooked, unilaterally bent central pores and large terminal fissures. Axial area narrow, linear, slightly widened in the middle; central area very small. Striæ parallel, slightly convergent at the poles. Transverse striæ stronger, but less numerous than the longitudinal striæ. Craticular plates present.

Dimensions .. Length 112–120 μ
Breadth 26–28 μ
Transverse striæ 16–17 in 10 μ
Longitudinal striæ 24–25 in 10 μ

Habitat .. Fresh-water. Powai Lake. Rare.

105. *Navicula cuspidata* Kütz. var. *ambigua* (Ehr.) Cleve

(Fig. 106)

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* The first two papers in this series have been published in this Journal Vol. 31 : 117–151 and Vol. 32 : 239–263.

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FIG. 105

Hustedt, Fr., Pascher's *Süsswasser-Flora*, Heft 10, 1930, P. 268, fig. 434; Skvortzow, B. W., Diatoms from Calcutta, India, *Philip. J. Sci.*, Vol. 58, 1935, p. 181, pl. 1, fig. 8; II. Fresh-water Algæ from Napier, *ibid.*, Vol. 67, 1938, p. 415, pl. 1, fig. 8; Venkataraman, G., A Systematic Account of some South Indian Diatoms, *Proc. Indian Acad. Sci.*, Vol. X, No. 6, Sect. B, 1939, p. 327, fig. 94.

Valves rhombic-lanceolate with produced, rostrate ends. Raphe thin and straight with hooked, central pores and large terminal fissures. Axial area narrow; central area slightly widened in the middle. Striæ not so numerous as in the type. Transverse striæ equal to the longitudinal striæ in number.

Dimensions	..	**Length 116–125 μ** **Breadth 27–28 μ** **Trans. and long. striæ 18–19 in 10 μ**
Habitat	..	**Fresh-water. Streams at Borivli, Kanheri Caves, Powai Lake and pools at Santa-Cruz. Common.**

106. *Navicula cuspidata* Kütz. var. *heribaudi* Peragallo

(Fig. 107)

Hustedt, Fr., Pascher's *Süsswasser-Flora*, Heft 10, 1930, p. 268, fig. 435.

Valves rhombic-lanceolate with broadly attenuated ends. Longitudinal striæ more numerous than the transverse striæ, the latter strongly radial.

Dimensions .. Length 86–90 μ
Breadth 19·8–20 μ
Longitudinal striæ 20–22 in 10 μ
Transverse striæ 14 in 10 μ

Habitat .. Fresh-water. Pond at Goregaon. Rare.

107. *Navicula cuspidata* Kütz. var. *major* Meister

(Fig. 108)

Abdul-Majeed, M., Fresh-water Algæ of the Panjab, Pt. I. Bacillariophyta (Diatomeæ), *Panjab University Publications*, Lahore, 1935, p. 23, pl. 6, fig. 1.

Frustules solitary and larger than the type. Valves elongated and rhombic-lanceolate. Ends produced and rounded. Raphe somewhat thick, with hooked, unilaterally-bent central pores. Axial and central areas as in the type. Transverse striæ less numerous than the longitudinal striæ.

Dimensions .. Length 192·8–205 μ
Breadth 45–46·4 μ
Longitudinal striæ 25–26 in 10 μ
Transverse striæ 15–17 in 10 μ.

Habitat .. Fresh-water. Powai Lake. Rare.

This form agrees with the description and figure given by Abdul-Majeed (1935) except that it is a larger and broader form.

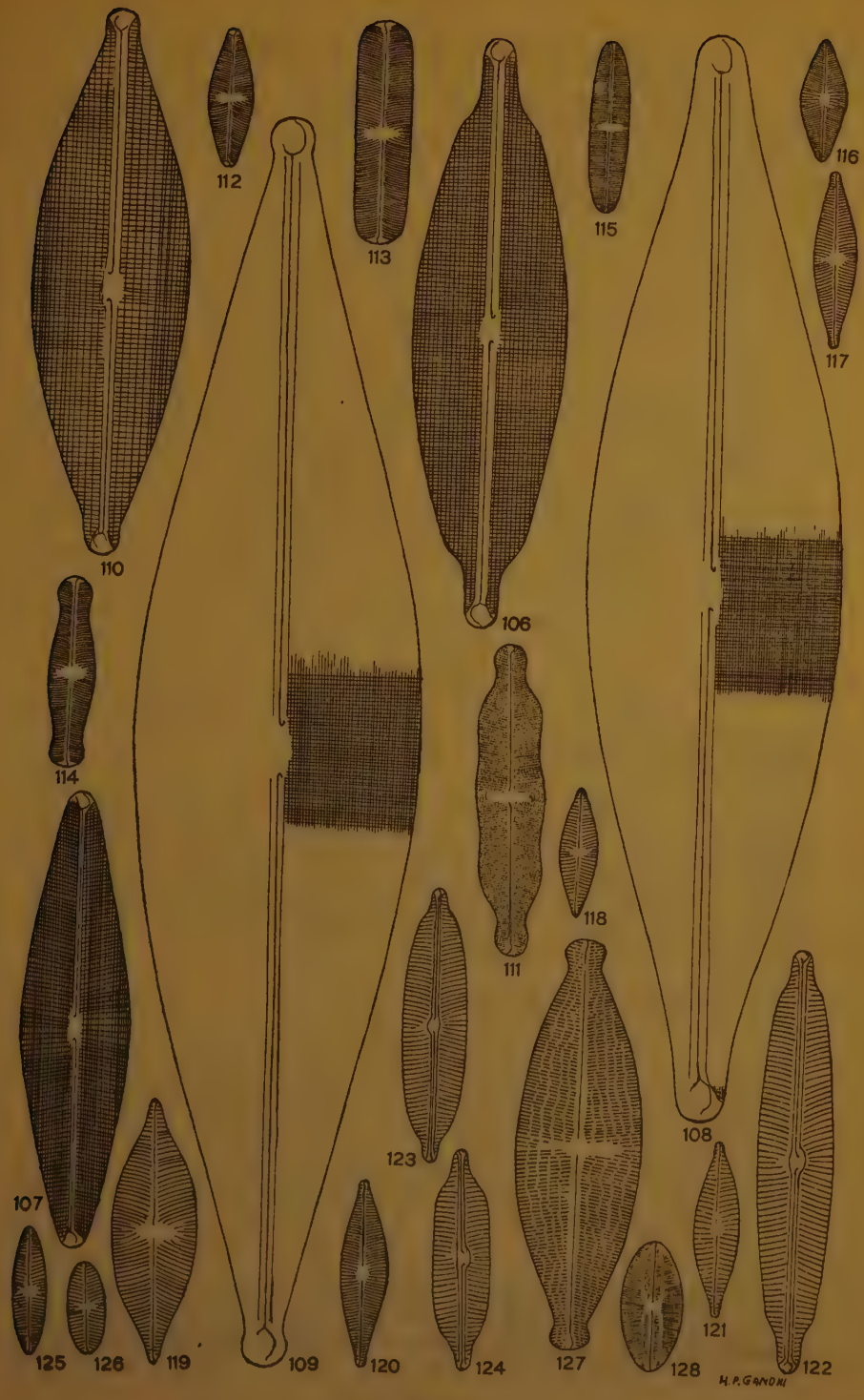
108. *Navicula cuspidata* Kütz. var. *major* Meister f. *robusta* forma nova.

(Fig. 109)

Frustula solitaria, libere natantia, amplissima atque robustissima. Valvæ rhombo-lanceolatæ, attenuatæ ad utrumque apicem, qui est constrictus atque capitatus. Raphe tenuis atque recta, ornata poris centralibus, unilateraliter inclinatis atque hamo similibus, ornata etiam fissuris terminalibus late curvatis. Area axialis angustissima, area centralis tenuiter dilatata ob interruptionem vel fractionem striarum longitudinalium in medio. Striæ longitudinales longius inter se distant quam striæ transversæ.

Frustula 225–230 μ longa, 48·6 μ lata, striæ longitudinales 18 in 10 μ, striæ transversæ 15 in 10 μ.

Frustules solitary, free-floating, very large and robust. Valves rhombic-lanceolate with attenuated, constricted, capitate ends. Raphe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FIGS. 106–128

thin and straight, with hooked, unilaterally-bent central pores and broadly curved, terminal fissures. Axial area very narrow; central area slightly widened due to interruption or breaking of the longitudinal striæ in the middle part. Longitudinal striæ more numerous than the transverse striæ.

Dimensions .. Length 225–230 μ
Breadth 48·6 μ
Longitudinal striæ 18 in 10 μ
Transverse striæ 15 in 10 μ

Habitat .. Fresh-water. Powai Lake. Rare.

The present form agrees with *N. cuspidata* Kütz. var. *major* Meister (Abdul-Majeed, *Bacillariophyta*, Pt. I, 1935, p. 23, pl. 6, fig. 1), except that the ends of this form are distinctly constricted and capitate, and not merely produced and round. Moreover, the valves are very robust and the longitudinal striæ almost equal the transverse striæ in number. In *N. cuspidata* var. *major* Meister, the longitudinal striæ are finer and more numerous than the transverse striæ. Hence, the present specimen is regarded as a new form of *N. cuspidata* Kütz. var. *major* Meister.

109. *Navicula cuspidata* Kütz. var. *conspicua* Venkataraman

(Fig. 110)

Venkataraman, G., A Systematic Account of some South Indian Diatoms, *Proc. Indian Acad. Sci.*, Vol. X, No. 6, Sect. B, 1939, p. 325, figs. 83, 88.

Valves rhombic to elliptical-lanceolate with slightly constricted and rounded ends. Axial area narrow; central area slightly widened. Raphe thin and straight, with hooked central pores bent unilaterally. Transverse striæ parallel, slightly convergent at the ends. Longitudinal striæ coarse, clear and prominent, closer towards the margins and wider near the middle. Central area widened due to breaking of the longitudinal striæ in the middle.

Dimensions .. Length 91·8–123 μ
Breadth 25–27 μ
Longitudinal striæ 8–13 in 10 μ
Transverse striæ 12–14 in 10 μ

Habitat .. Fresh-water. Pond at Goregaon, Powai Lake. Common.

Section *Naviculæ mesoleiæ* Cleve

110. *Navicula mutica* Kütz. var. *linearis* var. nova.

(Fig. 111)

Valvæ lineares, marginibus triundulatis, tenuissime fastigatæ ad utrumque apicem, qui est late rotundatus atque capitatus. Raphe tenuis atque recta, poris centralibus aliquantum unilateraliter inclinatis,

Area axialis angusta, area centralis vero rectangularis vel tenuiter dilatata ad margines, uno puncto ad latus ornata. Striæ radiales, tenues, sed distincte punctatæ.

Frustula 48–56 μ longa, 9–10·8 μ lata; striæ 30 in 10 μ.

Valves linear with triundulate margins, very slightly narrowing towards the ends which are broadly rounded and capitate. Raphe thin and straight, with central pores slightly bent unilaterally. Axial area narrow; central area rectangular or very slightly widened towards the margins, with an isolated punctum on one side. Striæ radial, fine but distinctly punctate.

Dimensions	..	Length 48–56 μ Breadth 9–10·8 μ Striæ 30 in 10 μ
Habitat	..	Fresh-water. Pools and puddles at Vile-Parle (anonymous collection). Rare.

This form agrees with *N. mutica* Kütz. (Hustedt, Fr., Pascher's *Süsswasser-Flora*, Heft 10, 1930, p. 274, fig. 453 *a*) in having an isolated punctum on one side of the central area, but differs in outline. It resembles *N. mutica* var. *nivalis* (Ehr.) Hust. (Hustedt, *op. cit.*, p. 275, fig. 453 *c*) in having triundulate margins, but it is linear and not linear-elliptical like the latter. Moreover, the middle undulation is not prominent. It is also a much longer and narrower form and the punctæ of the striæ, though very fine and closely placed, are distinct. It differs from *N. mutica* var. *pulchra* McCall (McCall, D., Fossil Diatoms of Tay District, *J. Linn. Soc. Lond.*, Botany, Vol. XLIX, No. 328, 1933, p. 245, fig. 12) in having rounded, capitate ends, instead of rostrate, capitate ends, while the radial striæ have fine instead of coarse punctæ. Moreover, the striæ in this form far exceed those of *N. mutica* var. *pulchra* McCall in number. Hence, it is regarded as a new variety of *N. mutica* Kütz.

Section *Naviculæ bacillares* Cleve

111. *Navicula pupula* Kütz.

(Fig. 112)

Van Heurck, *Treatise on the Diatomaceæ* (Trans. by W. Baxter), 1896, p. 225, pl. 5, fig. 226; Schönfeldt, Pascher's *Süsswasser-Flora*, Heft 10, 1913, p. 79, fig. 147; Hustedt, Fr., Pascher's *Süsswasser-Flora* Heft 10, 1930, p. 281, fig. 467 *a*; Skvortzow, B. W., Diatoms from Poyang Lake, Hunan, China, *Philip. J. Sci.*, Vol. 57, 1935, p. 469, pl. 1, figs. 30, 31; Diatoms from Kizaki Lake, Honshu Island, Nippon, *ibid.*, Vol. 61, 1936, p. 34, pl. 12, fig. 15.

Valves linear-lanceolate or subelliptical, with broadly rounded and slightly constricted ends. Raphe thin and straight. Polar areas present. Axial area very narrow, linear; central area rectangular, transversely widened. Striæ fine, radial and curved throughout.

Dimensions .. Length 25–30 μ
Breadth 7·5–8 μ
Striæ 25 in 10 μ

Habitat .. Fresh-water. Pond at Dahisar, Jogeswari, streams at Borivli and pools at Kanheri Caves. Very common.

112. *Navicula pupula* Kütz. var. *rectangularis* (Greg.) Grun.

(Fig. 113)

Schönfeldt, Pascher's *Süsswasser-Flora*, Heft 10, 1913, p. 79; Hustedt, Fr., Pascher's *Süsswasser-Flora*, Heft 10, 1930, p. 281, fig. 467 *b*.

Valves linear with parallel sides and broadly rounded ends. Raphe thin and straight. Polar areas present. Axial area very narrow, linear; central area rectangular, transversely widened. Striæ fine, radial and curved throughout; in the central region short and long striæ alternate as in the type.

Dimensions .. Length 30–41 μ
Breadth 8·5–10·8 μ
Striæ 20–25 in 10 μ

Habitat .. Fresh-water. Powai Lake, Vihar Lake, streams at Borivli, pools and puddles at Jogeswari. Common.

113. *Navicula pupula* Kütz. var. *capitata* Hust.

(Fig. 114)

Hustedt, Fr., Pascher's *Süsswasser-Flora*, Heft 10, 1930, p. 281, fig. 467 *c*.

Valves linear with slightly convex walls and broadly capitate rounded ends. In all other respects like the type.

Dimensions .. Length 34·2–45 μ
Breadth 9–11 μ
Striæ 22–24 in 10 μ.

Habitat .. Fresh-water. Streams at Borivli, pools at Kanheri Caves and Powai Lake. Common.

Section *Naviculæ minusculæ* Cleve

114. *Navicula densestriata* Hust.

(Fig. 115)

Hustedt, Fr., Pascher's *Süsswasser-Flora*, Heft 10, 1930, p. 288, fig. 485.

Valves linear-elliptic with almost parallel sides and broadly rounded ends. Raphe thin and straight. Axial area very narrow, linear; central area small, linear and transversely widened. Striæ extremely fine, perpendicular to the middle line; central striæ small.

Dimensions .. Length 29-32 μ
Breadth 5·4–6 μ
Striæ 30–32 in 10 μ

Habitat .. Fresh-water. Streams at Chembur Hills. Rare.

Section *Naviculæ heterostichæ* Cleve

115. *Navicula cocconeiformis* Gregory

(Fig. 116)

Gregory, W., Notice of some new species of British Fresh-water Diatomaceæ, *Quart. J. microscop. Sci.*, O.S., Vol. IV, 1856, p. 6, pl. 1, fig. 22; Schönfeldt, Pascher's *Süsswasser-Flora*, Heft 10, 1913, p. 89, fig. 181; Van Heurck, *Treatise on the Diatomaceæ* (Trans. by Baxter), 1896, pl. 228, p. 27, fig. 779; Hustedt, Fr., Pascher's *Süsswasser-Flora*, Heft 10, 1930, p. 290, fig. 493.

Valves rhombic-elliptical with broad, somewhat rounded ends. Raphe thin, with central pores distantly placed. Axial area narrow; central area extremely small, elliptical. Striæ throughout radial, finely punctate; at the centre short and long striæ alternate with each other.

Dimensions .. Length 20–27 μ
Breadth 8·5–9 μ
Striæ 23–25 in 10 μ

Habitat .. Fresh-water. Pools at Jogeswari, streams at Kanheri Caves. Common.

Section *Naviculæ lineolatæ* Cleve

116. *Navicula cryptocephala* Kütz.

(Fig. 117)

Van Heurck, *Treatise on the Diatomaceæ* (Trans. by Baxter), 1896, p. 180, pl. 3, fig. 122; Schönfeldt, Pascher's *Süsswasser-Flora*, Heft 10, 1913, p. 92, fig. 189; Hustedt, Fr., Pascher's *Süsswasser-Flora*, Heft 10, 1930, p. 295, fig. 496; Skvortzow, B. W., Diatoms from Poyang Lake, Hunan, China, *Philip. J. Sci.*, Vol. 57, 1935, p. 470, pl. 1, fig. 36; Diatoms from Kizaki Lake, Honshu Island, Nippon, *ibid.*, Vol. 61, 1936, p. 36, pl. 10, fig. 5.

Valves lanceolate with more or less capitate produced ends. Raphe thin and straight. Axial area very narrow; central area extended transversely, small. Striæ radial in the middle and convergent at the poles, indistinctly punctate.

Dimensions .. Length 28·8–32 μ
Breadth 7–7·2 μ
Striæ 16 in 10 μ

Habitat .. Fresh-water. Streams at Borivli, Powai Lake. Brackish water. Mahim creek, Chembur creek. Not very common.

117. *Navicula cryptocephala* Kütz. var. *veneta* (Kütz.) Grun.

(Fig. 118)

Van Heurck, *Treatise on the Diatomaceæ* (Trans. by Baxter), 1896, p. 181, pl. 3, fig. 123; Schönfeldt, Pascher's *Süsswasser-Flora*, Heft 10, 1913, p. 92; Hustedt, Fr., Pascher's *Süsswasser-Flora*, Heft 10, 1930, p. 295, fig. 497 *a*.

Valves linear-lanceolate, with slightly constricted ends. Raphe thin and straight. Axial area narrow; central area rectangular. Striæ radial in the middle and convergent at the ends, slightly longer striæ alternate with shorter ones in the middle.

Dimensions .. Length 23–25 μ
Breadth 6 μ
Striæ 15–17 in 10 μ

Habitat .. Brackish water. Mahim creek. Common.

118. *Navicula salinarum* Grun.

(Fig. 119)

Van Heurck, *Treatise on the Diatomaceæ* (Trans. by Baxter), 1896, p. 178, pl. 3, fig. 108; Schönfeldt, Pascher's *Süsswasser-Flora*, Heft 10, 1913, p. 92, fig. 187; Hustedt, Fr., Pascher's *Süsswasser-Flora*, Heft 10, 1930, p. 295, fig. 498; Skvortzow, B. W., Diatoms from Chengtu Szechwan, Western China, *Philip. J. Sci.*, Vol. 66, 1938, p. 485, pl. 4, fig. 5; Venkataraman, G., A Systematic Account of some South Indian Diatoms, *Proc. Indian Acad. Sci.*, Vol. X, No. 6, Sect. B, 1939, p. 328, fig. 95.

Frustules solitary, free-floating. Valves lanceolate-elliptical with more or less produced, acute ends. Raphe thin. Axial area very narrow; central area large and rounded. Striæ strongly radial in the middle and convergent at the ends or somewhat perpendicular to the middle line; in the centre short and long striæ alternate with each other.

Dimensions .. Length 47–50 μ
Breadth 14·4–15 μ
Striæ 14 in 10 μ

Habitat .. Brackish water. Mahim creek. Common.
Fresh-water. Powai Lake. Rare.
This form is slightly longer and broader than the type.

119. *Navicula simplex* Krasske

(Fig. 120)

Hustedt, Fr., Pascher's *Süsswasser-Flora*, Heft 10, p. 296, fig. 500.

Valves lanceolate with subcapitate ends. Raphe straight and thin with distantly placed central pores. Axial area narrow; central area small, oval. Striæ radial in the middle. strongly convergent at the ends.

Dimensions .. Length 32–33 μ
Breadth 8·6 μ
Striæ 17–18 in 10 μ

Habitat .. Brackish water. Mahim creek. Common.

This form agrees with the type in all respects except that it has subcapitate instead of rostrate ends.

120. *Navicula rostellata* Kütz.

(Fig. 121)

Hustedt, Fr., Pascher's *Süsswasser-Flora*, Heft 10, 1930, p. 297, fig. 502; Venkataraman, G., A Systematic Account of some South Indian Diatoms, *Proc. Indian Acad. Sci.*, Vol. X, No. 6, Sect. B, 1939, p. 329, fig. 90.

Valves lanceolate with small rostrate or produced ends. Raphe thin and straight. Axial area narrow; central area large, more or less circular. Striæ radial in the middle and slightly convergent at the poles; middle striæ shortened.

Dimensions .. Length 36–42 μ
Breadth 8–8·2 μ
Striæ 11–12 in 10 μ

Habitat .. Fresh-water. Pools at Wadala. Rare.

121. *Navicula viridula* Kütz.

(Fig. 122)

Van Heurck, *Treatise on the Diatomaceæ* (Trans. by Baxter), 1896, p. 179, pl. 3, fig. 115; Schönfeldt, Pascher's *Süsswasser-Flora*, Heft 10, 1913, p. 94, fig. 192; Hustedt, Fr., Pascher's *Süsswasser-Flora*, Heft 10, 1930, p. 297, fig. 503; Rich, F., Contributions to our Knowledge of the Fresh-water Algæ of Africa, 12. Some Diatoms from Victoria-falls, *Trans. Roy. Soc. S. Afr.*, Vol. 24, 1937, p. 214, pl. 9, fig. 1; Skvortzow, B. W., Diatoms from Argun River, Hsing-An-Pei Province, Manchaukuo, *Philip. J. Sci.*, Vol. 66, 1938, p. 55, pl. 1, fig. 16; pl. 2, fig. 30.

Valves linear-lanceolate with produced and broadly rounded ends. Raphe enclosed in siliceous ribs, central pores unilaterally bent, with distinct, terminal fissures. Axial area narrow; central area wide and suborbicular. Striæ strong, radial in the middle and slightly convergent at the poles.

Dimensions .. Length 66–79 μ
Breadth 13–14·4 μ
Striæ 9–10 in 10 μ

Habitat .. Fresh-water. Powai Lake, streams at Borivli Common.

In this form, siliceous ribs enclosing the raphe as described by Skvortzow, are seen.

122. *Navicula viridula* Kütz. var. *rostellata* (Cleve) Meister

(Fig. 123)

Abdul-Majeed, M., Fresh-water Algæ of the Panjab, Bacillariophyta (Diatomeæ), pt. I, *Panjab University Publications*, Lahore, 1935, p. 24, pl. 11, fig. 18.

Valves broadly linear, somewhat lanceolate with suddenly narrowed and produced subrostrate ends. Raphe thin, enclosed between siliceous ribs, with central pores bent unilaterally. Axial area very narrow and indistinct; central area rounded. Striæ strongly radial in the middle and slightly convergent at the poles.

Dimensions	..	Length 45–52 μ Breadth 10–10·8 μ Striæ 12 in 10 μ
Habitat	..	Fresh-water. Streams at Borivli, Powai Lake. Common.

This form agrees in outline with *N. viridula* var. *rostellata* as described and figured by Abdul-Majeed, except that it is slightly broader and has siliceous ribs enclosing the raphe. Skvortzow, however, describes siliceous ribs in *N. viridula* Kütz. (*Philip. J. Sci.*, Vol. 66, 1938, p. 55, pl. 1, fig. 16).

123. *Navicula viridula* Kütz. var. *rostrata* Skv.

(Fig. 124)

Skvortzow, B. W., Diatoms from Argun River, Hsing-An-Pei Province, Manchaukuo, *Philip. J. Sci.*, Vol. 66, 1938, p. 56, pl. 1, fig. 17.

Valves linear-lanceolate, with parallel margins and rostrate ends. Raphe enclosed in siliceous ribs. Axial area very narrow; central area broad, suborbicular. Striæ radial in the middle and convergent at the ends, lineate.

Dimensions	..	Length 37·8–40 μ Breadth 9–9·4 μ Striæ 10 in 10 μ
Habitat	..	Fresh-water. Streams at Borivli. Powai Lake. Rare.

124. *Navicula cincta* (Ehr.) Kütz.

(Fig. 125)

Van Heurck, *Treatise on the Diatomaceæ* (Trans. by Baxter), 1896, p. 178, pl. 3, fig. 105; Schönfeldt, Pascher's *Süsswasser-Flora*, Heft 10, 1913, p. 92, fig. 188; Hustedt, Fr., Pascher's *Süsswasser-Flora*, Heft, 10, 1930, p. 298, fig. 510; Skvortzow, B. W., Diatoms from Kenon Lake, Transbaikalia, Siberia, *Philip. J. Sci.*, Vol. 65, p. 409, pl. 1, figs. 22, 26.

Valves small, linear-lanceolate with broadly rounded ends. Raphe thin and straight. Axial area narrow; central area small and transverse. Striæ strongly radial, in the middle, convergent and delicate, at

the ends, somewhat lineate; middle striæ further apart from one another than those at the ends.

Dimensions .. Length 26–32 μ
Breadth 5·4–7 μ
Striæ 14–16 in 10 μ

Habitat .. Fresh-water. Streams at Borivli, Powai Lake. Brackish water. Chembur creek. Common.

125. *Navicula schönfeldii* Hust.

(Fig. 126)

Hustedt, Fr., Pascher's *Süsswasser-Flora*, Heft 10, 1930, p. 301, fig. 520.

Valves elliptical or somewhat elliptic-lanceolate with rounded ends. Raphe thin, straight. Axial area extremely narrow; central area rectangular. Striæ radial and strong, short and long striæ alternate in the middle.

Dimensions .. Length 18–20 μ
Breadth 6·5 μ
Striæ 14–15 in 10 μ

Habitat .. Fresh-water. Streams at Borivli, Powai Lake and Vihar Lake. Common.

126. *Navicula tuscula* (Ehr.) Grun.

(Fig. 127)

Van Heurck, *Treatise on the Diatomaceæ* (Trans. by Baxter), 1896, p. 206, pl. 4, fig. 166; Schönfeldt, Pascher's *Süsswasser-Flora*, Heft 10, 1913, p. 95, fig. 196; Hustedt, Fr., Pascher's *Süsswasser-Flora*, Heft 10. 1930, p. 308, fig. 552; Skvortzow, B. W., Diatoms from Ikeda Lake, Satsuma Province, Kiewsien Island, Nippon, *Philip. J. Sci.*, Vol. 62, 1937, p. 203, pl. 1, fig. 13; Diatoms from Olhan-Gate of Baikal Lake, Siberia, *ibid.*, Vol. 62, 1937, p. 332, pl. 8, fig. 3.

Valves elliptical with strongly capitate ends. Raphe thin and straight. Axial area narrow, linear; central area large, transversely extended. Striæ radial throughout, crossed by many longitudinal hyaline bands, hence irregularly interrupted.

Dimensions .. Length 72–77 μ
Breadth 22·5–23 μ
Striæ 13–14 in 10 μ

Habitat .. Fresh-water. Powai Lake. Fairly common.

Section *Naviculæ lyratæ* Cleve

127. *Navicula pygmæa* Kütz.

(Fig. 128)

Van Heurck, *Treatise on the Diatomaceæ* (Trans. by Baxter), 1896, p. 203, pl. 4, fig. 164; Schönfeldt, Pascher's *Süsswasser-Flora*, Heft 10,

1913, p. 98, fig. 207; Hustedt, Fr., Pascher's *Süsswasser-Flora*, Heft 10, 1930, p. 312, fig. 561; Venkataraman, G., A Systematic Account of some South Indian Diatoms, *Proc. Indian Acad. Sci.*, Vol. X, No. 6, Sect. B, 1939, p. 333, fig. 97.

Valves elliptical with broadly rounded ends. Raphe thin and straight, with closely placed central pores. Axial area very narrow and somewhat indistinct; central area small; lateral H-shaped area constricted in the central nodule. Striæ very fine, delicate, somewhat radial in the middle and convergent at the ends.

Dimensions	..	Length 23·4–28 μ Breadth 10–11 μ Striæ 26–30 in 10 μ.
Habitat	..	Brackish water. Mahim creek, Chembur creek. Very common. This form is slightly broader than the type.

Acknowledgement

The authors are grateful to Rev. Fr. H. Santapau, St. Xavier's College, Bombay for the Latin diagnosis of new forms described in this paper.

Description of Figures

N.B.—All the figures are under a magnification of ×820 approximately.

Fig. 105. *Navicula cuspidata* Kütz.

Figs. 106–128. Fig. 106. *Navicula cuspidata* Kütz. var. *ambigua* (Ehr.) Cleve. Fig. 107. *Navicula cuspidata* Kütz. var. *heribaudi* Peragallo. Fig. 108. *Navicula cuspidata* Kütz. var. *major* Meister. Fig. 109. *Navicula cuspidata* Kütz. var. *major* Meister forma *robusta* f. nov. Fig. 110. *Navicula cuspidata* Kütz. var. *conspicua* Venkataraman. Fig. 111. *Navicula mutica* Kütz. var. *linearis* var. nov. Fig. 112. *Navicula pupula* Kütz. Fig. 113. *Navicula pupula* Kütz. var. *rectangularis* (Gregory) Grun. Fig. 114. *Navicula pupula* Kütz. var. *capitata* Hust. Fig. 115. *Navicula densestriata* Hust. Fig. 106. *Navicula cocconeiformis* Gregory. Fig. 117. *Navicula cryptocephala* Kütz. Fig. 118. *Navicula cryptocephala* Kütz. var. *veneta* (Kutz.) Grun. Fig. 119. *Navicula salinarum* Grun. Fig. 120. *Navicula simplex* Krasske. Fig. 121. *Navicula rostellata* Kütz. Fig. 122. *Navicula viridula* Kütz. Fig. 123. *Navicula viridula* Kütz. var. *rostellata* (Cleve) Meister. Fig. 124. *Navicula viridula* Kütz. var. *rostrata* Skvortzow. Fig. 125. *Navicula cincta* (Ehr.) Kütz. Fig. 126. *Navicula schönfeldii* Hust. Fig. 127. *Navicula tuscula* (Ehr.) Grun. Fig. 128. *Navicula pygmæa* Kütz.

A NOTE ON HORMOGONE FORMATION IN *AULOSIRA IMPLEXA* BORN. ET FLAH. VAR. *CRASSA* DIXIT

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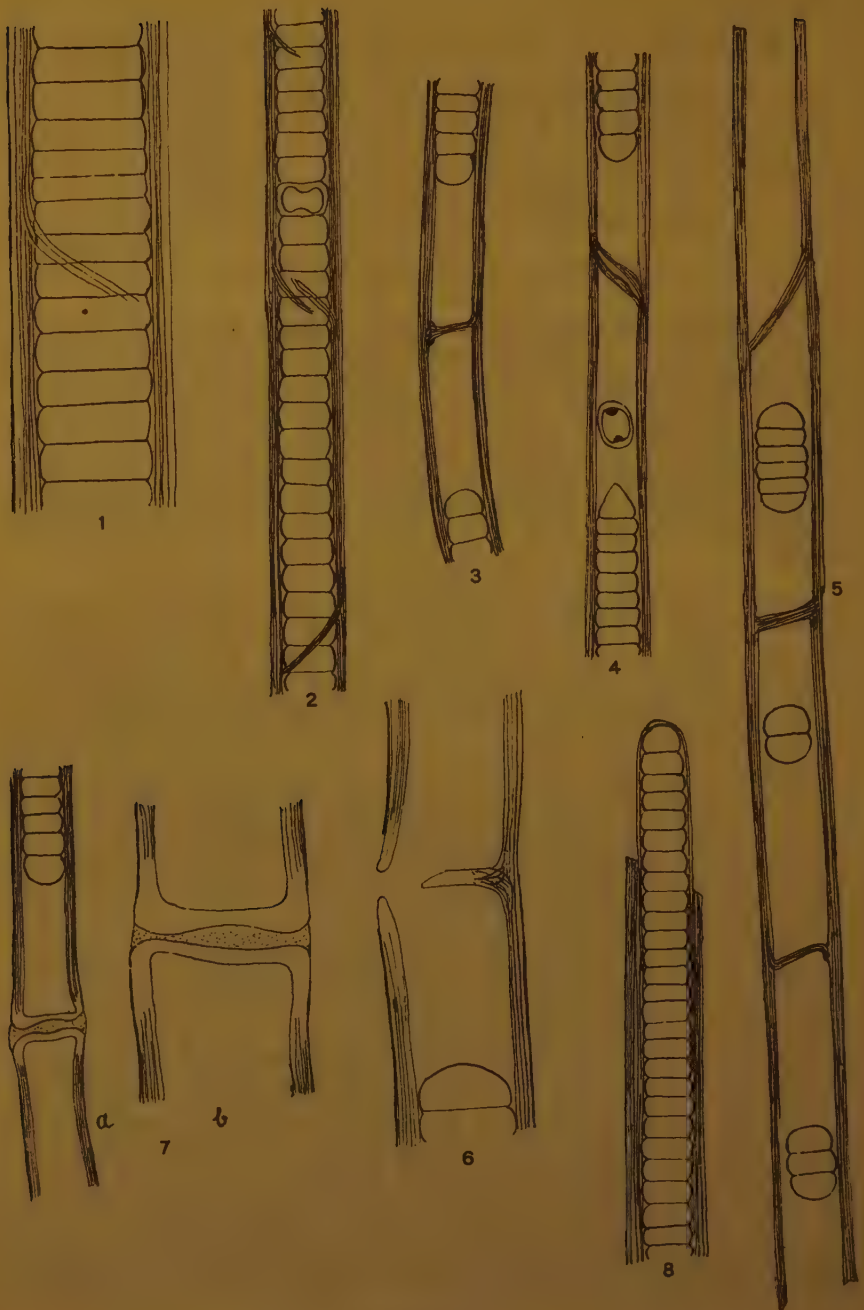
The formation of hormogones is a common feature in the Myxophyceæ. Bharadwaja (1933, p. 134) mentions four methods of hormogone formation, *viz.*, (1) as a result of dying of series of cells at certain points in the trichome; (2) by the secretion of dark-green intercellular substances between the cells, such secretions often taking the form of thick biconcave pads; (3) as a result of development of intercalary heterocysts; and (4) by the production of a single or a pair of biconcave cells with granular contents. In *Aulosira implexa* Born. et Flah. var. *crassa* Dixit, hormogone formation was observed in a manner differing from the above.

This form was collected from along the railway lines near Devarai Station on the Poona-Bangalore railway route. It was first described by Dixit (1936, p. 98), who mentions that spore formation was not observed by him. Here too, spore formation was not observed, but in the cold season, the formation of hormogones was observed in the following manner:—

Previous to the formation of hormogones, there is a break in the inner sheath on one side (Fig. 1) or sometimes on both the sides (Fig. 2). Such breaks occur at intervals along the filaments (Figs. 2, 5). This is followed by the deflection of the broken part or parts of the sheath so that the broken portion lies across the cells, dividing the trichome into a number of unequal sections (Fig. 2).

Subsequent to this, the cells of the trichome near the deflected portion of the sheath die (Fig. 3). If the deflection occurs near a heterocyst, the cells in between the heterocyst and the deflection die while the heterocyst gets separated from the remaining part of the trichome (Fig. 4). Thus the deflections encase small pieces of trichomes consisting of two to many cells, which function as hormogones (Fig. 5).

Escape of the hormogones ultimately occurs due to gelatinisation of the deflected portion and the outer sheath near it. Gelatinisation may be gradual, from one side of the filament to the other (Fig. 6) or it may occur simultaneously in the whole deflection (Fig. 7 *a* and *b*). The filament may thus break into a number of parts. When the deflections occur at long intervals, the encased portions of the trichome are fairly large. In such cases, the lower end of the trichome



FIGS. 1–8

remains within the filament, but the upper portion near the breaks in the wall begins to grow vigorously, ultimately emerging through the break and continuing growth outside (Fig. 8).

This method of hormogone formation, as far as the authors are aware, has not been recorded elsewhere.

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BHARADWAJA, Y. 1933. Contributions to our knowledge of the Myxophyceæ of India. Ann Bot. 47: 117–43.

DIXIT, S. C. 1936. The Myxophyceæ of the Bombay Presidency, India I. Proc. Indian Acad. Sci. B. 3: 93-106.

Explanation of Figures

TEXT FIGS. 1–8. Fig. 1. Part of a filament showing deflection of the inner sheath to one side, ×854. Fig. 2. Part of a filament showing three deflections —one from both sides, ×300. Fig. 3. Part of a filament showing a gap on either side of a deflection, due to death and the subsequent disappearance of cells, ×300. Fig. 4. Part of a filament with a heterocyst separated from the trichome and gaps on either side of a deflection, ×300. Fig. 5. Part of a filament showing 2 to many-celled hormogones, ×300. Fig. 6. A portion of a filament showing a break in the deflected area, ×854. Fig. 7 *a* and *b*. A portion of a filament showing gelatinisation of the deflected portion, ×854. Fig. 8. Emergence of hormogone through a break.

A CONTRIBUTION TO THE DIATOM FLORA OF SOUTH INDIA*

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The number of papers dealing with Indian diatoms is very small. Venkataraman (1939) was the first to give an account of some freshwater diatoms of South India. In his paper he has summarised the literature pertaining to the records of Indian diatoms up to 1939. Iyengar and Subrahmanyan (1943) published a paper on the fossil diatoms of the Karewas of Kashmir. Later, Subrahmanyan (1946) gave an account of the marine plankton diatoms of the Madras coast. Recently, Gonzalves and Gandhi (1952, 1953) have published on the diatoms of Bombay and Salsette. Apart from the paper by Venkataraman (1939), no other account of the freshwater diatoms of South India is available. Hence the writer made a study of the freshwater diatom flora of some different parts of South India. The study revealed in addition to the forms already recorded by Venkataraman, a number of forms which have not been recorded by him and an account of these is given below.

The material for study was collected mostly by the writer at various places and at different times between 1942 and 1946, while some material was kindly placed at the disposal of the writer by Prof. M. O. P. Iyengar. Collections were made from various parts of the city of Madras, Vandalur in Chingleput District, Kambakkam in Nellore District, Kodaikanal on the Palni Hills, Ootacamund on the Nilgiri Hills and Mangalore in South Kanara District. All the collections were preserved in 4% formalin.

For purposes of identification, the diatoms were first cleaned by treating with concentrated sulphuric acid to which a few crystals of potassium dichromate were added. The cleaned diatoms were then mounted in styrax for microscopic examination.

In the following account, the classification followed by Hustedt (1930, 1931–32) has been adopted. Altogether 58 species are described, of which two species, four varieties and four forms are new.

BACILLARIOPHYTA (DIATOMEÆ)

Order	*CENTRALES*
Suborder	DISCINEÆ
Family	COSCINODISCACEÆ
Subfamily:	MELOSIROIDEÆ
Genus	*Melosira* Agardh, 1824

* Thesis (in part) approved for the Degree of Master of Science of the University of Madras.

1. *Melosira distans* (Ehr.) Kütz.

(Fig. 9)

(Van Heurck, *Traité des Diatomeés*, 1899, p. 442, pl. 19, fig. 616; Boyer, C. S., *Syn. N. Am. Diat.*, pt. 1, 1926, p. 30; Hustedt, Fr., *Pascher's Süsswasserflora*, Heft 10, 1930, p. 92, fig. 53 *a*, *b*; Hustedt, Fr., *Rabenhorst's Kryptogamenflora*, Bd. VII, Teil 1, 1930, p. 262, fig. 110; Schmidt, A., *Atlas*, pl. 182, figs. 4, 5).

Frustules cylindrical, united to form short, slender, chain-like colonies; valve face flat, 5–6 μ in diameter; margin of valve provided with short projecting teeth which aid in uniting the frustules of the colony; mantel short, 4–6 μ in height; sulcus present as an angular furrow; a distinct pseudosulcus also present; suprasulcian portion of the girdle punctate, punctæ 13–14 in 10 μ, coarse and disposed in more or less transverse rows; cell wall thick; inner mantel line convex.

Habitat.—Irrigation tank, Vandalur.

Subfamily: FRAGILARIOIDEÆ

Genus *Fragilaria* Lyngbye, 1819.

2. *Fragilaria capuciana* Desmaziers var. *courtallensis* var. nov.

(Figs. 3, 4)

Frustulia aspectu zonali linearia, rectangularia, unita per valvarum facies in lacinias longas; valvulæ lineares, lateribus parallelis, 75–90 μ longæ, 10–11 μ latæ, subito fastigatæ ad apices; apices rostrati; striæ distinctæ, ca. 10 in 10 μ; pseudoraphe angusta, linearis; area centralis sæpe unilateralis.

Habitat.—Rivulis collinis, Courtallum.

Frustules in girdle view linear, rectangular, united by their valve faces to form long bands; valves linear, with parallel sides, 75–90 μ long, 10–11 μ broad; suddenly tapering at the ends; ends rostrate; striæ distinct, about 10 in 10 μ; pseudoraphe narrow, linear; central area often unilateral.

Habitat.—Hill stream, Courtallum.

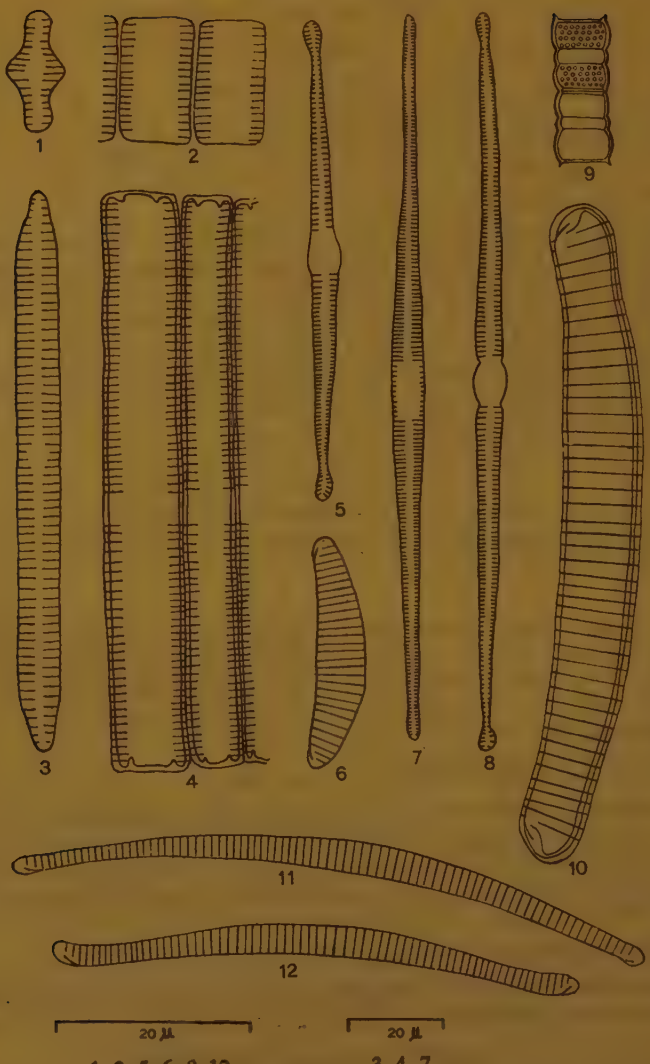
This form agrees with *F. capucina* (Hustedt, 1931–32), but is broader and has striæ wider apart. Hence it is described as a new variety.

3. *Fragilaria construens* (Ehr.) Grun.

(Figs. 1, 2)

(Van Heurck, *Traité des Diatomeés*, 1899, p. 325, pl. 11, fig. 450; Boyer, C. S., *Syn. N. Am. Diat.*, 1926, p. 188; Hustedt, Fr., *Pascher's Süsswasserflora*, Heft 10, 1930, p. 140, fig. 135; Hustedt, Fr., *Rabenhorst's Kryptogamenflora*, Bd. VII, Teil 2, Lief 1–4, 1931–32, p. 156, fig. 670 *a–c*; Schmidt, A., *Atlas*, pl. 296, figs. 25–47.)

Frustules in girdle view rectangular, united by their valve faces to form long bands; valve 9–15 μ long, 5–9 μ broad, inflated in the



FIGS. 1–12. Figs. 1, 2. *Fragilaria construens* (Ehr.) Grun. Figs. 3, 4. *Fragilaria capucina* Desmaziers var. *courtallensis* var. nov. Fig. 5. *Synedra rumpens* Kütz. Fig. 6. *Eunotia pectinalis* (Dillw ? Kütz.) Raben. var. *minor* (Kütz.) Raben. f. *intermedia* Krasske. Fig. 7. *Synedra acus* Kütz. Fig. 8. *Synedra rumpens* Kütz. var. *familiaris* (Kütz.) Grun. Fig. 9. *Melosira distans* (Ehr.) Kütz. Fig. 10. *Eunotia monodon* Ehr. var. *maior* W. Sm. Fig. 11. *Eunotia lunaris* (Ehr.) Grun. var. *capitata* Grun. Fig. 12. *Eunotia lunaris* (Ehr.) Grun.

middle; ends rounded; valve surface striated, striæ 15–16 in 10 μ; pseudoraphe more or less lanceolate, without a central area.

Habitat.—Freshwater pond in Botanical Gardens, Ootacamund.

Genus *Synedra* Ehrenberg, C. G., 1830

4. *Synedra acus* Kütz.

(Fig. 7)

(Van Heurck, *Traité des Diatomeés*, 1899, p. 311, pl. 10, fig. 420; Boyer, C. S., *Syn. N. Am. Diat.*, 1926, p. 201 ; Hustedt, Fr., *Pascher's Süsswasserflora*, Heft 10, 1930, p. 155, fig. 170; Hustedt, Fr., *Rabenhorst's Kryptogamenflora*, Bd. VII, Teil 2, Lief 1–4, 1931–32, p. 201, fig. 693 *a*; Schmidt, A., *Atlas*, pl. 303, figs. 7, 8.)

Frustules free-floating, linear in girdle view, dilated at the ends; valve narrow, linear to lanceolate, somewhat broad in the middle, gradually tapering towards the ends, 120–200 μ long, 3–5 μ broad in the middle, about 1·5 μ at the ends; ends obtuse; trans-apical striæ fine, about 12 in 10 μ; pseudoraphe narrow, linear; central area generally without striæ.

Habitat.—Storage tank in Triplicane, Madras.

5. *Synedra rumpens* Kütz.

(Fig. 5)

(Hustedt, Fr., *Pascher's Süsswasserflora*, Heft 10, 1930, p. 156, fig. 175; Hustedt, Fr., *Rabenhorst's Kryptogamenflora*, Bd. VII, Teil 2, Lief 1–4, 1931–32, p. 207, fig. 697 *a, b*)

Valve slender lanceolate, gradually tapering, 45–55 μ long, 2–3 μ broad; ends slightly capitate; striæ 13–15 in 10 μ; pseudoraphe narrow, linear; central area slightly inflated, free of striations.

Habitat.—Irrigation tank, Vandalur.

This form agrees with the type, but the striæ seem to be wider apart. According to Hustedt (1931–32), the striæ are 19–20 in 10 μ.

var. *familiaris* (Kütz.) Grun.

(Fig. 8)

Valve long and slender, gradually tapering, 70–72 μ long, 2–3 μ broad; ends distinctly capitate; valve surface finely striated, striæ 11–12 in 10 μ; pseudoraphe narrow, linear; valve margin constricted on either side of the central area.

Habitat.—Irrigation tank, Vandalur.

Suborder RAPHIDIOIDEÆ

Family EUNOTIACEÆ

Subfamily: EUNOTIOIDEÆ

Genus *Eunotia* Ehrenberg, C. G., 1837

6. *Eunotia pectinalis* (Dillw. ? Kütz.) Raben. var. *minor* (Kütz.) Raben. f. *intermedia* Krasske

(Fig. 6)

(Hustedt, Fr., *Rabenhorst's Kryptogamenflora*, Bd. VII, Teil 2, Lief 1–4, 1931–32, p. 298, fig. 763, *l-o*.)

Frustules united by their valves to form ribbon-like colonies; valve lunate, with well bent dorsal margin, 20–25 μ long, 4–5 μ broad; ventral margin slightly concave; ends rounded; valve surface striated; striæ 14–15 in 10 μ.

Habitat.—Paddy field, Mangalore.

The forms are very small and show close similarity to *E. faba* (Ehr.) Grun. and *E. veneris* (Kütz.) O. Müller. The slightly concave ventral margin, however, distinguishes the present form from these other two species.

7. *Eunotia lunaris* (Ehr.) Grun.

(Fig. 12)

(Hustedt, Fr., *Rabenhorst's Kryptogamenflora*, Bd. VII, Teil 2, Lief 1–4, 1931–32, p. 302, fig. 769 *a*, *b*.)

Valve lunate, with well bent dorsal margin, and concave ventral margin, 48–56 μ long, 2–3 μ broad; ends reflexed, obtuse; valve surface striated, striæ finely punctate, 15 in 10 μ.

Habitat.—Paddy field, Mangalore.

var. *capitata* Grun.

(Fig. 11)

(Hustedt, Fr., *Rabenhorst's Kryptogamenflora*, Bd. VII, Teil 2, Lief 1–4, 1931–32, p. 304, fig. 769 *c*.)

Valve lunate, gradually becoming attenuated towards the ends, 60–70 μ long, 2–3 μ broad; ends capitate; striæ 14 in 10 μ.

Habitat.—Hill stream, Kambakkam.

8. *Eunotia monodon* Ehr. var. *maior* W. Sm.

(Fig. 10)

(Hustedt, Fr., *Rabenhorst's Kryptogamenflora*, Bd. VII, Teil 2, Lief 1–4, 1931–32, p. 306, fig. 772 *c*.)

Valve arcuate, broad, narrowing at the ends, 65–75 μ long, 7–9 μ broad; striæ 8–9 in 10 μ.

Habitat.—Attached to a *Cladophora* growing in a well in Triplicane, Madras, collected by Prof. M. O. P. Iyengar.

9. *Eunotia diodon* Ehr.

(Fig. 13)

(Van Heurck, *Traité des Diatomeés*, 1899, p. 303, pl. 30, figs. 829, 830; Hustedt, Fr., *Pascher's Süsswasserflora*, Heft 10, 1930, p. 173; Hustedt, Fr., *Rabenhorst's Kryptogamenflora*, Bd. VII, Teil 2, Lief 1–4, 1931–32, p. 276, fig. 742; Schmidt, A., *Atlas*, pl. 270, figs. 14–18.)

Valve well bent, 24–29 μ long, 5–8 μ broad; dorsal margin wavy, with two prominences; ventral margin distinctly concave; striæ distinct, coarse, 10–11 in 10 μ.

Habitat.—Rain water pool, Elliott's Beach, Madras, collected by Prof. M. O. P. Iyengar.

10. *Eunotia robusta* Ralfs. var. *tetraodon* (Ehr.) Ralfs.

(Fig. 16)

(Van Heurck, *Traité des Diatomeés*, 1899, p. 303, pl. 9, fig. 382; Hustedt, Fr., *Rabenhorst's Kryptogamenflora*, Bd. VII, Teil 2, Lief 1–4, 1931–32, p. 273, fig. 740 *i*; Schmidt, A., *Atlas*, pl. 270, figs. 11, 12.)

Valve well bent, with lunate dorsal margin and concave ventral margin, 70–85 μ long, 16–18 μ broad; dorsal margin with four undulations; ends sub-acute; striæ distinct, coarse, 10–11 in 10 μ.

Habitat.—Hill stream, Kambakkam.

The present form is similar to *E. robusta* var. *tetraodon*, but is much larger. Also, the dorsal margin shows undulations only and not four gibbosities as is usually met with in this variety. Still, the spacing of the striæ is typical of the variety.

11. *Eunotia lapponica* A. Cleve

(Fig. 14)

(Hustedt, Fr., *Pascher's Süsswasserflora*, Heft 10, 1930, p. 180, fig. 236; Hustedt, Fr., *Rabenhorst's Kryptogamenflora*, Bd. VII, Teil 2, Lief 1–4, 1931–32, p. 295, fig. 762 *a*, *b*; Schmidt, A., *Atlas*, pl. 289, figs. 41–48.)

Valve arcuate, well bent, 50–60 μ long, 5–6 μ broad; dorsal margin slightly depressed towards the ends; ends broadly rounded, slightly subcapitate; ventral margin distinctly concave; striæ fine, 14–15 in 10 μ.

Habitat.—Paddy field, Mangalore.

12. *Eunotia gracilis* (Ehr.) Raben.

(Fig. 18)

(Van Heurck, *Traité des Diatomeés*, 1899, p. 300, pl. 9, fig. 368; Boyer, C. S., *Syn. N. Am. Diat.*, pt. 2, 1927, p. 217; Hustedt, Fr., *Rabenhorst's Kryptogamenflora*, Bd. VII, Teil 2, Lief 1–4, 1931–32, p. 305, fig. 771; Schmidt, A., *Atlas*, pl. 271, fig. 7.)

Valve long and slender, nearly straight, 130–150 μ long, 7–8 μ broad; ends slightly swollen; a faint line is present starting from the end nodule and running close to the dorsal margin; ventral margin slightly concave; valve surface finely striated, striæ 12–13 in 10 μ.

Habitat.—River Cooum, Madras; Hill stream, Kambakkam.

FIGS. 13–26. Fig. 13. *Eunotia diodon* Ehr. Fig. 14. *Eunotia lapponica* A. Cleve. Fig. 15. *Eunotia sibirica* Cleve. Fig. 16. *Eunotia robusta* Ralfs. var. *tetraodon* (Ehr.) Ralfs. Fig. 17. *Caloneis schumanniana* (Grun.) Cleve var. *biconstricta* Grun. f. *interrupta* f. nov. Fig. 18. *Eunotia gracilis* (Ehr.) Raben. FIGS. 19–21. *Achnanthes affinis* Grun. Figs. 22–24. *Achnanthes minutissima* Kütz. Fig. 25. *Caloneis bacillum* (Grun.) Mereschkowsky. Fig. 26. *Eunotia flexuosa* (Bréb.) Kütz. var. *bicapitata* Hust.

13. *Eunotia sibirica* Cleve

(Fig. 15)

(Hustedt, Fr., *Rabenhorst's Kryptogamenflora*, Bd. VII, Teil 2, Lief 1–4, 1931–32, p. 310, fig. 776; Schmidt, A., *Atlas*, pl 381, figs. 24–28.)

Valve well bent, 34–40 μ long, 6–8 μ broad; dorsal margin markedly depressed in the middle, each half having two prominences; ventral margin distinctly concave; ends obtuse; striæ distinct, 9–10 in 10 μ.

Habitat.—River Cooum, Madras.

14. *Eunotia flexuosa* (Bréb.) Kütz. var *bicapitata* Hust.

(Fig. 26)

(Hustedt, Fr., *Rabenhorst's Kryptogamenflora*, Bd. VII, Teil 2, Lief 1–4, 1931–32, p. 312, fig. 778.)

Valve almost straight with parallel sides, slightly tapering at the ends, 100–130 μ long, 5–6 μ broad; ends capitate; striæ finely punctate, 13–14 in 10 μ.

Habitat.—Paddy field, Mangalore.

Suborder MONORAPHIDINEÆ

Family ACHNANTHACEÆ

Subfamily: ACHNANTHOIDEÆ

Genus *Achnanthes* Bory, 1822

15. *Achnanthes minutissima* Kütz.

(Figs. 22–24)

(Hustedt, Fr., *Pascher's Süsswasserflora*, Heft 10, 1930, p. 198, fig. 274.)

Frustules reflexed in girdle view; valve linear, with slightly tapering margins and obtuse ends, 7–16 μ long, 2–4 μ broad; lower valve with median, straight raphe; valve surface very finely striated.

Habitat.—Freshwater garden pond, Presidency College, Madras. The forms met with in the collection were small, not exceeding 16 μ in length, though the range in length is given as 4–50 μ by Hustedt (1931–32). The striæ, moreover, were very indistinct and so could not be counted or drawn. The indistinctness of the striæ may be due to the extremely small size of the frustules.

16. *Achnanthes affinis* Grun.

(Figs. 19–21)

(Cleve, P. T., *Syn. Nav. Diat.*, pt. 2, 1893, p. 190; Hustedt, Fr., *Rabenhorst's Kryptogamenflora*, Bd. VII, Teil 2, Lief 1–4, 1931–32, p. 381, fig. 826.)

Frustules reflexed in girdle view; valve linear-lanceolate, 19–42 μ long, 2–3 μ broad; upper valve with linear, narrow, median pseudoraphe; lower valve with straight median raphe; central area transversely extended to the margin; valve surface finely striated, striæ about 30 in 10 μ, slightly radial throughout.

Habitat.—Hill stream, Kodaikanal.

Suborder BIRAPHIDINEÆ

Family NAVICULACEÆ

Subfamily: NAVICULOIDEÆ

Genus *Caloneis* Cleve, 1894.

17. *Caloneis bacillum* (Grun.) Mereschkowsky

(Fig. 25)

(Hustedt, Fr., *Pascher's Süsswasserflora*, Heft 10, 1930, p. 236, fig. 360.)

Valve elliptic, with more or less parallel sides, tapering at the ends, 17–32 μ long, 4–7 μ broad; ends acute; valve surface striated, striæ 21–24 in 10 μ, parallel towards the middle, slightly radial at the ends; axial area somewhat broad, central area broadly rectangular, not marked with striæ; a very fine marginal line present.

Habitat.—Rain water pool, Triplicane, Madras; Irrigation tank, Vandalur.

18. *Caloneis schumanniana* (Grun.) Cleve var. *biconstricta* Grun. f. *interrupta* f. nov.

(Fig. 17)

Valvulæ lineari-lanceolatæ, constrictæ ad utrumque polum, 40–48 μ longæ, 6–8 μ latæ; apices cuneati, acuti; valvularum facies striata, striis 18 in 10 μ, radialibus, interruptis in medio; area axialis angusta, lanceolata; area centralis absque striis; linea marginalis obscura.

Habitat.—Irrigationis lacu, Vandalur.

Valve linear-lanceolate, constricted towards either pole, 40–48 μ long, 6–8 μ broad; ends wedge-shaped, acute; valve surface striated, striæ about 18 in 10 μ, radial, interrupted in the middle; axial area narrow, lanceolate; central area without striations; marginal line faint.

Habitat.—Irrigation tank, Vandalur.

The form comes very close to *C. schumanniana* var. *biconstricta* but is distinguished by the fact that the striæ are interrupted in the middle. Also, the ends are acute and there is no lunate marking in the central area.

Genus *Frustulia* (Agardh) Grunow, 1865

19. *Frustulia rhomboides* (Ehr.) De-Toni var. *saxonica* (Rab.) De-Toni

(Figs. 27, 28)

(Hustedt, Fr., *Pascher's Süsswasserflora*, Heft 10, 1930, p. 221, fig. 325; Schmidt, A., *Atlas*, pl. 369, figs. 4, 5.)

Frustules elliptic, rhomboid in valve view, 48–60 μ long, 12–14 μ broad; ends rounded, slightly constricted; raphe in siliceous thickening

of the valve, extending from the central nodule to either polar nodule; siliceous thickening constricted at the central nodule.

Habitat.—Paddy field, Mangalore; Hill stream, Kambakkam.

There were two forms of this diatom, one in a collection from a paddy field in Mangalore and another from a hill stream at Kambakkam. The Mangalore form (Fig. 27) showed all the characteristic features. The Kambakkam form (Fig. 28) showed an obtuse valve end which was not constricted. Also, there was no constriction of the siliceous thickening of the valve at the central nodule.

Genus *Neidium* Pfitzer, 1871

20. *Neidium bisulcatum* (Lagerstedt) Cleve

(Fig. 34)

(Hustedt, Fr., *Pascher's Süsswasserflora*, Heft 10, 1930, p. 242, fig. 374.)

Valve linear, elliptic, with almost parallel sides, 48–62 μ long, 7–8 μ broad; ends rounded; valve surface finely striated, striæ delicate, 12–14 in 10 μ, slightly radial; a delicate longitudinal, hyaline, marginal line present; axial area narrow, linear; central area dilated; raphe simple, turned in opposite directions in central nodule.

Habitat.—Rain water pool in Elliott's beach, Madras, collected by Prof. M. O. P. Iyengar.

21. *Neidium productum* (W. Sm.) Cleve

(Fig. 29)

(Hustedt, Fr., *Pascher's Süsswasserflora*, Heft 10, 1930, p. 245, fig. 383.)

Valve linear-elliptic, with almost parallel sides, suddenly tapering at the ends; 80–90 μ long, 22–25 μ broad; ends rostrate, subcapitate; valve surface finely striated, striæ 16–17 in 10 μ, slightly radial, interrupted at either margin by two longitudinal, wavy lines; axial area narrow, linear; central area dilated; raphe median, turned in opposite directions at central nodule; polar nodules well developed.

Habitat.—Freshwater pond, Botanical Gardens, Ootacamund.

Genus *Diploneis* Ehrenberg, 1840

22. *Diploneis puella* (Schum. ?) Cleve

(Fig. 32)

(Cleve, P. T., *Syn. Nav. Diat.*, pt. 1, 1894, p. 92; Hustedt, Fr., *Pascher's Süsswasserflora*, Heft 10, 1930, p. 250, fig. 394.)

Valve elliptic, with rounded ends, 18–25 μ long, 8–10 μ broad; valve surface costate, costæ thick and distinct, 11–12 in 10 μ, continued into the furrows as large alveoli; central nodule large, dilated

FIGS. 27–36. Figs. 27, 28. *Frustulia rhomboides* (Ehr.) De-Toni var. *saxonica* (Rab.) De-Toni. Fig. 29. *Neidium productum* (W. Sm.) Cleve. Fig. 30. *Navicula cuspidata* Kütz. f. *indica* f. nov. Fig. 31. *Anomœneis rhomboidea* spec. nov. f. *minor* f. nov. Fig. 32. *Diploneis puella* (Schum ?) Cleve. Fig. 33. *Anomoneis rhomboidea* spec. nov. Fig. 34. *Neidium bisulcatum* (Lagerstedt) Cleve. Fig. 35. *Stauroneis anceps* Ehr. Fig. 36. *Navicula spicula* (Dickie) Cleve var. *pulneyensis* var. nov.

with narrow pro'ongations; furrows somewhat broad, following the course of the prolongations of the central nodule.

Habitat.—Attached to a *Cladophora* growing in a well in Triplicane, Madras, collected by Prof. M. O. P. Iyengar.

Genus *Stauroneis* Ehrenberg, 1843

23. *Stauroneis anceps* Ehr.

(Fig. 35)

(Smith, W., *Syn. Brit. Diat.*, Vol. I, 1853, p. 60, pl. 19, fig. 190; Cleve, P. T., *Syn. Nav. Diat.*, pt. 1, 1894, p. 147; Van Heurck, *Traité des Diatomeés*, 1899, p. 160, pl. 1, fig. 55; Boyer, C. S., *Syn. N. Am. Diat.*, pt. 2, 1927, p. 422; Hustedt, Fr., *Pascher's Süsswasserflora*, Heft 10, 1930, p. 256, fig. 405.)

Valve linear-lanceolate, 65–80 μ long, 9–14 μ broad; valve ends slightly subcapitate; striæ fine, radial, 20–24 in 10 μ; axial area distinct, lanceolate, somewhat broad; central area stauroid, stauros linear, reaching the margin.

Habitat.—Irrigation tank, Vandalur.

The forms met with possess a distinct lanceolate axial area and so are different from the recorded forms of the speices. It is very difficult to distinguish the species into varieties, as the species is highly variable. Cleve (1894), however, distinguishes two groups of varieties, those with protracted ends which are not capitate and those with capitate ends. The forms in the present collection have subcapitate ends which are not protracted. There is some resemblance to *S. phœnicenteron*, but the present form does not have punctæ disposed in wavy longitudinal rows.

Venkataraman (1939) has recorded a form of *S. anceps* with slightly produced subcapitate ends and with indistinct axial area. The present form is probably a different variety.

Genus *Anomœoneis* Pfitzer, 1871

24. *Anomœoneis rhomboidea* spec. nov.

(Fig. 33)

Valvulæ rhomboideæ vel lineari-lanceolatæ, apicibus rotundatis, 50–60 μ longæ, 9–11 μ latæ; valvularum facies minute striata, striis tenuiter radialibus, 28–30 striis in 10 μ, interruptis triplici vel quadruplici linea longitudinali undulata hyalina ad utrumque latus areæ axialis : area axialis angusta, linearis; area centralis dilatata, ampla atque rhomboidea.

Habitat.—Rivulis collinis, Kambakkam.

Valve rhomboid to linear-lanceolate, with rounded ends, 50–60 μ long, 9–11 μ broad; valve surface finely striated, striæ slightly radial, 28–30 in 10 μ, interrupted by 3–4 longitudinal, wavy, hyaline lines on either side of the axial area; axial area narrow, linear; central area dilated, big and rhomboid.

Habitat.—Hill stream, Kambakkam.

FIGS. 37–51. Fig. 37. *Navicula inflata* Donk. Fig. 38. *Navicula confervacea* Kütz. Fig. 39. *Navicula cryptocephala* Kütz. var. *veneta* (Kütz.) Grun. Figs. 40, 41. *Navicula lanceolata* (Ag. ?) Kütz. var. *tenella* A.S. Fig. 42. *Cymbella ventricosa* Kütz. Fig. 43. *Pinnularia gibba* Ehr. Fig. 44. *Pinnularia viridis* (Nitzsche) Ehr. var. *intermedia* Cleve. Figs. 45, 46. *Amphora veneta* (Kütz.) Hust. Fig. 47. *Pinnularia modesta* Grun. Figs. 48, 51. *Cymbella amphicephala* Nægeli. Fig. 49. *Cymbella reinhardtii* Grun. FIG. 50. *Cymbella ventricosa* Kütz. var. *depressa* var. nov.

In its fine striations and the nature of the longitudinal wavy lines, the form comes close to *A. serians* (Bréb.) Cleve var. *brachysira* (Bréb.) Hust., but is quite different in the sape of the central area. In the

present form, it is big and rhomboid. This character does not appear to have been recorded for any other species of *Anomœoneis*.

f. *minor* f. nov.

(Fig. 31)

Ut in typo, sed valvulæ plus minusve ellipticæ apicibus rotundatis, 18–32 μ longæ, 5–7 μ latæ; striæ transversales radiales, 28–30 in 10 μ, interruptæ duplici linea longitudinali hyalina in utroque latere areæ axialis.

Habitat.—Rivulis collinis, Kambakkam.

Same as the type, but valve more or less elliptical with rounded ends, 18–32 μ long, 5–7 μ broad; transverse striæ radial, 28–30 in 10 μ, interrupted by two longitudinal hyaline lines on either side of the axial area.

Habitat.—Hill stream, Kambakkam.

This form is similar to the type described above, but is very much smaller. The shape is more elliptical and the valve ends more rounded. There are only two longitudinal lines. The spacing of the transverse striæ, however, is the same as in the type.

Genus *Navicula* Bory, 1822.

Section *Orthosticheæ*.

25. *Navicula cuspidata* Kütz. f. *indica* f. nov.

(Fig. 30)

Valvulæ elliptico-lanceolatæ, apicibus obtusis, 140–150 μ longæ, 28–30 μ latæ; area axialis angusta, linearis; striæ transapicales parallelæ, 12–13 in 10 μ; striæ longitudinales nullæ.

Habitat.—Lacu aquæ dulcis, Chetput, Madras.

Valve elliptic-lanceolate, with obtuse ends, 140–150 μ long, 28–30 μ broad; axial area narrow, linear; trans-apical striæ parallel, 12–13 in 10 μ; longitudinal striæ absent.

Habitat.—Freshwater pond, Chetput, Madras.

This form has no longitudinal striæ. Also, the transverse striæ are wider apart than in the type. The spacing of the striæ and the absence of the longitudinal striæ distinguish this form from all other forms of this species.

26. *Navicula spicula* (Dickie) Cleve var. *pulneyensis* var. nov.

(Fig. 36)

Valvulæ angustæ, lineari-lanceolatæ, apicibus obtusis, 40–48 μ longæ, 5–6 μ latæ; area axialis indistincta; area centralis tenuiter rotundata; pori centralis raphidis inter se vicini; noduli polaris ornati fissuris commæ similibus; striæ transapicales parallelæ, tenues, ca. 18 in 10 μ.

Habitat.—Rivulis collinis, Kodaikanal.

Valve narrow, linear-lanceolate, with obtuse ends, 40–48 μ long, 5–6 μ broad; axial area indistinct; central area slightly rounded; central pores of the raphe close together; polar nodules with comma-like fissures; trans-apical striæ parallel, fine, about 18 in 10 μ.

Habitat.—Hill stream, Kodaikanal.

In general appearance, this form shows similarity to *N. spicula* (Dickie) Cleve. The present variety is distinguished by (1) the wider spacing of the striæ and (2) the comma-like fissures of the polar nodules.

27. *Navicula inflata* Donk.

(Fig. 37)

(Cleve, P. T., *Syn. Nav. Diat.*, pt. 1, 1894, p. 139.)

Valve lanceolate, with capitate ends 28 μ long, 7 μ broad; axial area narrow, central area small; striæ about 20 in 10 μ in the middle and about 25 in 10 μ at the ends, radial; median striæ alternately long and short.

Habitat.—Freshwater pond, Botanical Gardens, Ootacamund.

Section *Entoleiæ*

28. *Navicula confervacea* Kütz.

(Fig. 38)

(Cleve, P. T., *Syn. Nav. Diat.*, pt. 1, 1894, p. 133; Hustedt, Fr. *Pascher's Süsswasserflora*, Heft 10, 1930, p. 278, fig. 460; Schmidt, A *Atlas*, pl. 297, figs. 77, 78.)

Frustules united by their valves to form long bands; valve broadly lanceolate, obtuse to subacute, 16–20 μ long, 8–9 μ broad; axial area lanceolate; striæ 22–24 in 10 μ, finely punctate, radial throughout.

Habitat.—Paddy field, Mangalore.

The form recorded here has striæ which are closer together. Also, the frustule is shorter and broader than recorded so far.

Section *Lineolatæ*

29. *Navicula cryptocephala* Kütz. var. *veneta* (Kütz.) Grun.

(Fig. 39)

(Cleve, P. T., *Syn. Nav. Diat.*, Pt. 2, 1895, p. 14; Hustedt, Fr., *Pascher's Süsswasserflora*, Heft 10, 1930, p. 295, fig. 497 *a*.)

Valve lanceolate with slightly capitate ends, 17–25 μ long, 4–6 μ broad; axial area indistinct; central area small; striæ 15–16 in 10 μ, slightly radial in the middle, convergent at the ends.

Habitat.—Rain water pool, Triplicane, Madras.

Variations have been observed in the shape of the frustule and also in the nature of the ends. The valve is lanceolate to elliptical in shape, and even shows a slight asymmetry in some of the frustules.

Valve ends vary from slightly subcapitate to rostrate capitate conditions. But the nature of the spacing of striæ is constant.

30. *Navicula lanceolata* (Ag. ?) Kütz. var. *tenella* A.S.

(Figs. 40, 41)

(Cleve, P. T., *Syn. Nav. Diat.*, pt. 2, 1895, p. 22.)

Valve narrow, lanceolate, 28–34 μ long, 6–8 μ broad; axial area indistinct; central area merging with axial area; striæ 12–15 in 10 μ, closer together at the ends than in the middle, radial throughout.

Habitat.—Freshwater pond, Botanical Gardens, Ootacamund.

Some of the forms possess valves which are broader and striæ which are radial in the middle and convergent at the ends.

Genus *Pinnularia* Ehrenberg, C. G., 1843

Section *Tabellariæ*

31. *Pinnularia gibba* Ehr.

(Fig. 43)

(Hustedt, Fr., *Pascher's Süsswasserflora*, Heft 10, 1930, p. 327.)

Valve linear, inflated in the middle and at the ends, 50–60 μ long, 9–10 μ broad; ends broadly rounded; striæ 10–11 in 10 μ, radial in the middle and convergent at the ends, crossed by narrow, longitudinal band; axial area narrow, dilated in the middle.

Habitat.—Irrigation tank, Vandalur.

Section *Brevistriatæ*

32. *Pinnularia modesta* Grun.

(Fig. 47)

(Cleve, P. T., *Syn. Nav. Diat.*, pt. 2, 1895, p. 87.)

Valve linear-lanceolate, with rounded ends, gradually tapering from the middle, 34–40 μ long, 6–7 μ broad; axial area narrow; central area slightly dilated in the middle; striæ 20 in 10 μ, almost parallel in the middle, convergent at the ends.

Habitat.—Gravel pool, Vandalur.

This form is slightly different from the type in having a narrow axial area which is slightly dilated in the middle.

Section *Complexæ*

33. *Pinnularia viridis* (Nitzsche) Ehr. var. *intermedia* Cleve

(Fig. 44)

(Cleve, P. T., *Syn. Nav. Diat.*, pt. 2, 1895, p. 91; Hustedt, Fr., *Pascher's Süsswasserflora*, Heft 10, 1930, p. 335.)

Valve linear, with almost parallel sides, attenuated towards the ends, 70–110 μ long, 14–16 μ broad; ends rounded; striæ 8–9 in 10 μ, radial in the middle, convergent at the ends, crossed by narrow longitudinal band; axial area $\frac{1}{4}$ the breadth of the valve; central area slightly wider.

Habitat.—Rain water pool, Elliott's Beach, Madras, collected by Prof. M. O. P. Iyengar.

Subfamily: GOMPHOCYMBELLOIDEÆ

Genus *Amphora* Ehrenberg, 1840

34. *Amphora veneta* (Kütz.) Hust.

(Figs. 45, 46)

(Hustedt, Fr., *Pascher's Süsswasserflora*, Heft 10, 1930, p. 345, fig. 631.)

Frustules more or less elliptical, constricted in the middle, 24 μ long, 10 μ broad; valve 3 μ broad, lunate, with convex dorsal margin and slightly concave ventral margin; dorsal margin slightly constricted in the middle; ends reflexed, obtuse; raphe close to ventral margin; striæ about 20 in 10 μ, wider apart in the middle, radial.

Habitat.—Beach pool, Triplicane, Madras, collected by Prof. M. O. P. Iyengar.

Genus *Cymbella* Agardh, 1830

35. *Cymbella reinhardtii* Grun.

(Fig. 49)

(Cleve, P. T., *Syn. Nav. Diat.*, pt. 1, 1894, p. 162; Hustedt Fr., *Pascher's Süsswasserflora*, Heft 10, 1930, p. 354, fig. 644.)

Valve naviculoid, lanceolate, with convex dorsal and ventral margins, 22–25 μ long, 7–8 μ broad; ends slightly subcapitate; striæ radial, coarsely punctate, about 14 in 10 μ; axial area indistinct; central area small; raphe nearly straight.

Habitat.—Gravel pool, Vandalur.

The present form differs from the type in having coarsely punctate striæ.

36. *Cymbella amphicephala* Nægeli

(Fig. 48)

(Cleve, P. T., *Syn. Nav. Diat.*, pt. 1, 1894, p. 164; Hustedt, Fr., *Pascher's Süsswasserflora*, Heft 10, 1930, p. 355, fig. 651.)

Valve naviculoid, lanceolate, with convex dorsal and ventral margins, 33–38 μ long, 8–9 μ broad; ends rostrate subcapitate; striæ radial, coarsely punctate, 9–10 in 10 μ in the middle, 12–13 in 10 μ at the ends; axial area indistinct; central area small; raphe slightly arcuate; terminal fissures comma-like.

Habitat.—Freshwater garden pond, Presidency College, Madras; Hill stream, Kodaikanal.

The forms met with had narrower valves and possessed striæ placed wider apart than in the type. In some specimens collected at Kodaikanal, the striæ were closer together along the ventral margin than along the dorsal margin. Moreover, the ends were rost ate, without being subcapitate.

37. *Cymbella ventricosa* Kütz.

(Fig. 42)

(Smith, W., *Syn. Brit. Diat.*, Vol. II, 1859, p. 68, pl. 55, fig. 346; Cleve, P. T., *Syn. Nav. Diat.*, pt. 1, 1894, p. 168; Van Heurck, *Traité des Diatomeés*, 1899, p. 150, pl. 1, fig. 49; Hustedt, Fr., *Pascher's Süsswasserflora*, Heft 10, 1930, p. 359, fig. 661.)

Frustules enclosed in mucilaginous tubes; valve lunate, with a well bent dorsal margin, 16–42 μ long, 5–9 μ broad; ventral margin straight, sometimes slightly gibbous in the middle; ends obtuse; striæ 10–12 in 10 μ, radial, coarsely punctate; raphe straight; terminal fissures turned downwards; axial area somewhat broad; central area somewhat dilated.

Habitat.—Storage tank at Triplicane Post Office, Madras.

var. *depressa* var. nov.

(Fig. 50)

Valvulæ fortiter asymmetricæ, margine dorsali distincte convexo, 16–33 μ longæ, 7–10 μ latæ; margo ventralis biarcuatus, ornatus tenui sed clara depressione media; apices obtusi, non-numquam aliquantum constricti in latere dorsali; striæ 9–10 in 10 μ, distincte punctatæ, radiales; area axialis aliquantum lata, area centralis aliquantum dilatata.

Habitat.—in Lacu aquae dulcis in horto, Presidency College, Madras.

Valve strongly asymmetrical, with markedly convex dorsal margin, 16–33 μ long, 7–10 μ broad; ventral margin biarcuate, with a slight but definite median depression; ends obtuse, sometimes slightly constricted on the dorsal side; striæ 9–10 in 10 μ, distinctly punctate, radial; axial area somewhat broad, central area somewhat dilated.

Habitat.—Freshwater garden pond, Presidency College, Madras.

This form comes very close to *C. ventricosa*, but differs from it in its ventral margin being slightly but definitely depressed in the middle.

Genus *Gomphonema* Agardh, 1824

38. *Gomphonema sphærophorum* Ehr.

(Fig. 58)

(Cleve, P. T., *Syn. Nav. Diat.*, pt. 1, 1894, p. 185; Hustedt, Fr., *Pascher's Süsswasserflora*, Heft 10, 1930, p. 372, fig. 695; Schmidt, A., *Atlas*, pl. 239, figs. 37–39.)

FIGS. 52–64. Fig. 52. *Gomphonema gracile* Ehr. var. *lanceolata* (Kütz.) Cleve. Fig. 53. *Gomphonema gracile* Ehr. Fig. 54. *Gomphonema tergestinum* (Grun.) Fricke. Fig. 55. *Gomphonema acuminatum* Ehr. var. *turris* Ehr. Fig. 56. *Gomphonema intricatum* Kütz. Fig. 57. *Gomphonema angustatum* (Kütz.) Raben. var. *producta* Grun. Fig. 58. *Gomphonema sphærophorum* Ehr. Fig. 59. *Gomphonema macropunctatum* spec. nov. Fig. 60. *Gomphonema olivaceum* (Lyngbye) Kütz. var. *calcarea* Cleve. Fig. 61. *Gomphonema longiceps* Ehr. var. *subclavata* Grun. Fig. 62. *Gomphonema olivaceum* (Lyngbye) Kütz. Fig. 63. *Gomphonema abbreviatum* Kütz. var. *pulneyensis* var. nov. Fig. 64. *Gomphonema abbreviatum* f. *minor* f. nov.

Frustules at the ends of branched mucilaginous stalks; valve clavate, with capitate apex and narrow, rostrate base, 30–40 μ long, 8–10 μ broad; striæ 10–11 in 10 μ, slightly radial and curved; axial area narrow; central area small.

Habitat.—Upper reaches of River Adyar, Madras.

The present form has slightly curved radial lines while in the type they are nearly straight.

39. *Gomphonema macropunctatum* spec. nov.

(Fig. 59)

Valvulæ lanceolatæ, gradatim fastigatæ ad basim, 17–20 μ longæ, 4–5 μ latæ; apex tenuiter subcapitatus vel rotundatus, basis obtusa; striæ 11–12 in 10 μ, radiales, punctatæ, magnæ; area axialis angusta; area centralis parva, unilateralis, ornata punctis segragatis.

Habitat.—Stagno glareoso, Vandalur.

Valve lanceolate, gradually tapering to the base, 17–20 μ long, 4–5 μ broad; apex slightly subcapitate to rounded, base obtuse; striæ 11–12 in 10 μ, radial, punctate, punctæ big; axial area narrow; central area small, unilateral, with an isolated puncta.

Habitat.—Gravel pool, Vandalur.

This form can be readily distinguished from all other smaller species of *Gomphonema* by the coarse big punctæ forming the striations.

40. *Gomphonema angustatum* (Kütz.) Raben. var. *producta* Grun.

(Fig. 57)

(Cleve, P. T., *Syn. Nav. Diat.*, pt. 1, 1894, p. 181; Hustedt, Fr., *Pascher's Süsswasserflora*, Heft 10, 1930, p. 373, fig. 693; Schmidt, A., *Atlas*, pl. 234, fig. 26.)

Valve clavate, gradually tapering to the base, 25–31 μ long, 9–10 μ broad; apex subcapitate; base rostrate; striæ almost parallel, about 12 in 10 μ; axial area indistinct; central area unilateral, with an indistinct stigma.

Habitat.—Irrigation tank, Vandalur.

41. *Gomphonema intricatum* Kütz.

(Fig. 56)

(Cleve, P. T., *Syn. Nav. Diat.*, pt. 1, 1894, p. 181; Hustedt, Fr., *Pascher's Süsswasserflora*, Heft 10, 1930, p. 376, fig. 697; Schmidt, A., *Atlas*, pl. 236, figs. 1–8.)

Valve linear, slightly gibbous in the middle, 50–60 μ long, about 7 μ broad; apex and base rounded; striæ 8–9 in 10 μ, radial; axial area indistinct, narrow; central area transversely extended.

Habitat.—Fresh water pond, Botanical Gardens, Ootacamund.

42. *Gomphonema gracile* Ehr.

(Fig. 53)

(Cleve, P. T., *Syn. Nav. Diat.*, pt. 1, 1894, p. 182; Hustedt, Fr., *Pascher's Süsswasserflora*, Heft 10, 1930, p. 376, fig. 702; Schmidt, A., *Atlas*, pl. 236, fig. 16.)

Valve lanceolate, with rounded apex and base, 53–59 μ long, 9–10 μ broad; striæ slightly radial, about 14 in 10 μ; axial area very narrow; central area also narrow, transverse.

Habitat.—Paddy field, Mangalore.

This form differs from the type in having rounded apex and base, but agrees in other respects. The rounded ends are similar to those in *G. gracile* var. *dichotomum*.

var. *lanceolata* (Kütz.) Cleve

(Fig. 52)

(Cleve, P. T., *Syn. Nav. Diat.*, pt. 1, 1894, p. 183; Hustedt, Fr., *Pascher's Süsswasserflora*, Heft 10, 1930, p. 376, fig. 703; Schmidt, A., *Atlas*, pl. 237, figs. 9–10.)

Valve linear-lanceolate, with acute to apiculate apex, 67–70 μ long, 10–11 μ broad; striæ about 9–10 in 10 μ, distinctly punctate, almost parallel to radial; axial area narrow; central area small, unilateral.

Habitat.—Irrigation tank, Vandalur.

This variety has striæ more distantly placed than in the forms described by Cleve and Hustedt. It shows resmblances to *G. acuminatum* as well as to *G. lanceolatum*. The nature of the striæ, however, is characteristic.

43. *Gomphonema tergestinum* (Grun.) Fricke

(Fig. 54)

(Hustedt, Fr., *Pascher's Süsswasserflora*, Heft 10, 1930, p. 377, fig. 719; Schmidt, A., *Atlas*, pl. 234, figs. 39–43.)

Valve clavate, broad above and attenuate towards the base, 50–55 μ long, 12–13 μ broad; apex broadly rounded; base obtuse; striæ coarsely punctate, radial, about 10 in 10 μ; axial area narrow; central area small, unilateral.

Habitat.—Upper reaches of the River Adyar, Madras.

44. *Gomphonema longiceps* Ehr. var. *subclavata* Grun.

(Fig. 61)

(Hustedt, Fr., *Pascher's Süsswasserflora*, Heft 10, 1930, p. 375, fig. 705.)

Valve lanceolate, slightly gibbous in the middle, 32–36 μ long, 9–10 μ broad; ends rounded, apex more broadly than the base; striæ

coarsely punctate, 9 in 10 μ almost parallel in the middle and slightly radial at the ends; axial area narrow; central area transverse, with an isolated puncta.

Habitat.—Attached to a *Cladophora* growing in a well in Triplicane, Madras, collected by Prof. M. O. P. Iyengar.

45. *Gomphonema acuminatum* Ehr. var. *turris* Ehr.

(Fig. 55)

(Cleve, P. T., *Syn. Nav. Diat.*, pt. 1, 1894, p. 184; Hustedt, Fr., *Pascher's Süsswasserflora*, Heft 10, 1930, p. 372, fig. 687; Schmidt, A., *Atlas*, pl. 239, figs. 11–15.)

Valve clavate, with gradualiy tapering lower half and biconstricted upper half, 34–65 μ long, 10–13 μ broad; apex generally subcapitate; base obtuse to subacute; striæ 10–13 in 10 μ, distinctly punctate, slightly radial; median stria opposite to stigma, short; axial area narrow; central area small, unilateral.

Habitat.—Freshwater garden pond, Presidency College, Madras; River Cooum, near Aminjikarai, Madras.

46. *Gomphonema olivaceum* (Lyngbye) Kütz.

(Fig. 62)

(Cleve, P. T., *Syn. Nav. Diat.*, pt. 1, 1894, p. 188; Hustedt, Fr., *Pascher's Süsswasserflora*, Heft 10, 1930, p. 378, fig. 719; Schmidt, A., *Atlas*, pl. 233, figs. 9–16.)

Valve clavate, with margins gradually tapering from the middle downwards, 15–24 μ long, 5 μ broad; apex slightly subcapitate to rounded; base obtuse; striæ 10–12 in 10 μ; slightly radial, faint; axial area indistinct; stigma absent.

Habitat.—Rain water pool, Triplicane, Madras.

var. *calcarea* Cleve

(Fig. 60)

(Cleve, P. T., *Syn. Nav. Diat.*, pt. 1, 1894, p. 188; Hustedt, Fr., *Pascher's Süsswasserflora*, Heft 10, 1930, p. 379, fig. 721; Schmidt, A., *Atlas*, pl. 233, figs. 18–21).

Valve clavate, with broadly rounded apex and attenuated base, 40–45 μ long, 9 μ broad; striæ about 12 in 10 μ, radial in the middle and parallel at the ends, not distinctly punctate; axial area indistinct; central area small; stigma absent.

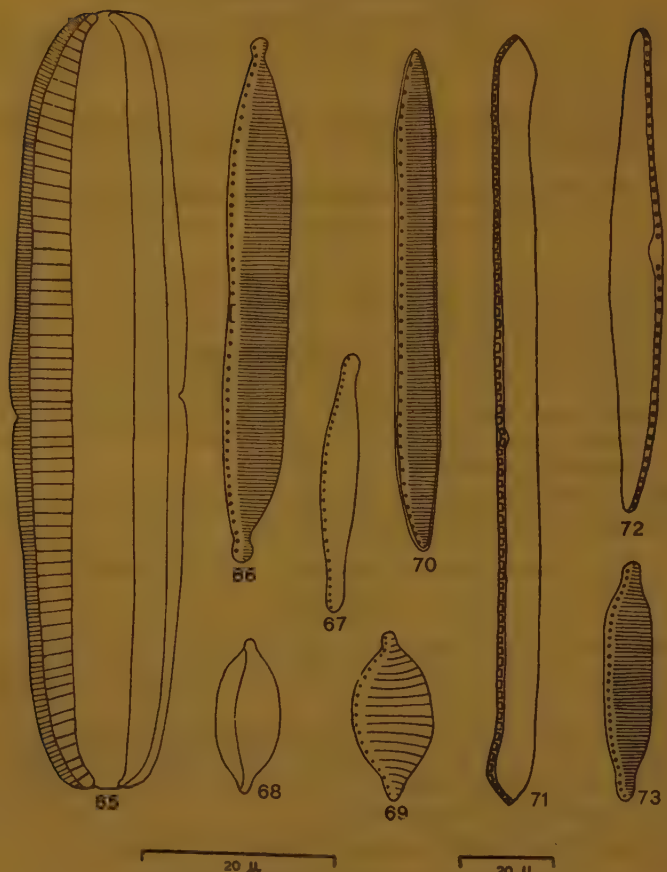
Habitat.—Hill stream, Kodaikanal.

47. *Gomphonema abbreviatum* Kütz.

f. *minor* f. nov.

(Fig. 64)

Typo persimile; valvulæ lineares, apice late rotundato, 26–28 μ longæ, 4–5 μ latæ; valvulæ margine gradatim fastigato ex apice deorsum;



FIGS. 65–73. Fig. 65. *Rhopalodia parallella* (Grun.) O. Müll. Fig. 66. *Hantzschia amphioxys* (Ehr.) Grun. f. *capitata* O. Müll. Fig. 67. *Nitzschia microcephala* Grun. Figs. 68, 69. *Nitzschia tryblionella* Hantzsch. var. *debilis* (Arnott) A. Meyer. Fig. 70. *Nitzschia recta* Hantzsch. Fig. 71. *Nitzschia scalaris* (Ehr.) W. Sm. Fig. 72. *Nitzschia sigma* (Kütz.) W. Sm. Fig. 73. *Nitzschia fonticola* Grun.

striæ tenuiter radiales, 11–12 in 10 μ; area axialis lata, linerari-lanceolata.

Habitat.—Rivulis collinis, Kodaikanal.

Very similar to the type; valve linear, with broadly rounded apex, 26–28 μ long, 4–5 μ broad; valve margin gradually tapering from apex downwards; striæ slightly radial, 11–12 in 10 μ; axial area broad, linear-lanceolate.

Habitat.—Hill stream, Kodaikanal.

The present form is distinguished from the type in its much smaller size and in possessing striæ which are slightly radial.

var. *pulneyensis* var. nov.

(Fig. 63)

Valvulæ lanceolatæ, apice late rotundato, basi obtusa, 32–44 μ longæ, 7–9 μ latæ; valvulæ margo tenuiter constrictus ad apicem atqe ad basim; striæ breves, tenuiter radiales, 11–12 in 10 μ; area axialis lata, lineari-lanceolata, tenuiter dilatata ad medium.

Habitat.—Rivulis collinis, Kodaikanal.

Valve lanceolate, with broadly rounded apex and obtuse base, 32–44 μ long, 7–9 μ broad; valve margin slightly constricted towards apex and base; striæ short, slightly radial, 11–12 in 10 μ; axial area broad, linear-lanceolate, slightly widened in the middle.

Habitat.—Hill stream, Kodaikanal.

In the present variety, the striæ are wider apart than in *G. abbreviatum*, and are radial in arrangement. Further, the valve margin is constricted towards apex and base. For these reasons, this is considered to be a new variety.

Family EPITHEMIACEÆ

Subfamily: RHOPALODIOIDEÆ

Genus *Rhopalodia* O. Müller

48. *Rhopalodia parallella* (Grun.) O. Müller

(Fig. 65)

(Hustedt, Fr., *Pascher's Süsswasserflora*, Heft 10, 1930, p. 389, fig. 739; Schmidt, A., *Atlas*, pl. 253, figs. 1–13.)

Frustules linear in girdle view, with almost parallel sides, constricted in the middle, 130–140 μ long, 22–24 μ broad; valve linear, with slightly arcuate dorsal margin and straight ventral margin; ends slightly reflexed, obtuse; costæ about 7 in 10 μ; striæ 15–16 in 10 μ.

Habitat.—Hill stream, Kodaikanal.

Family NITZSCHIACEÆ

Subfamily: NITZSCHIOIDEÆ

Genus *Hantzschia* Grunow, 1880

49. *Hantzschia amphioxys* (Ehr.) Grun. f. *capitata* O. Müll.

(Fig. 66)

(Hustedt, Fr., *Pascher's Süsswasserflora*, Heft 10, 1930, p. 394, fig. 748; Schmidt, A., *Atlas*, pl. 329, figs. 13–14.)

Valve linear, 80–85 μ long, 9–10 μ broad; dorsal margin slightly arcuate, depressed in the middle; ventral margin almost straight, tapering at the ends; ends capitate; keel punctæ 6–7 in 10 μ, striæ about 18 in 10 μ.

Habitat.—Irrigation tank, Vandalur.

Genus *Nitzschia* Hassal, 1845

Section Tryblionellæ

50. *Nitzschia tryblionella* Hantzsch. var. *debilis* (Arnott) A. Meyer

(Figs. 68, 69)

(Hustedt, Fr., *Pascher's Süsswasserflora*, Heft 10, 1930, p. 400, fig. 759; Schmidt, A., *Atlas*, pl. 332, fig. 17.)

Valve elliptical, with pronouncedly convex margins, 14–17 μ long, 4–7 μ broad; ends rostrate to cuneate; keel punctæ eccentric, 14–15 in 10 μ; striæ clear, coarsely punctate, divergent, 16–20 in 10 μ.

Habitat.—Rain water pool, Triplicane, Madras.

Section Scalares

51. *Nitzschia scalaris* (Ehr.) W. Sm.

(Fig. 71)

(Hustedt, Fr., *Pascher's Süsswasserflora*, Heft 10, 1930, p. 409, fig. 783; Schmidt, A., *Atlas*, pl. 33, figs. 1–3.)

Valves linear, with dilated and obliquely truncated ends, 160 μ long, 8 μ broad; keel punctæ 3–4 in 10 μ, interrupted in the middle; striæ coarse.

Habitat.—River Cooum, near Aminjikarai, Madras.

Section Lineares

52. *Nitzschia recta* Hantzsch

(Fig. 70)

(Hustedt, Fr., *Pascher's Süsswasserflora*, Heft 10, 1930, p. 416, fig. 801.)

Valve linear, with tapering rounded ends, 50–56 μ long, 5–7 μ broad; keel punctæ 10 in 10 μ; striæ fine, close, 40–45 in 10 μ.

Habitat.—Storage tank in Triplicane Post Office, Madras.

Section Lanceolatæ

53. *Nitzchia microcephala* Grun.

(Fig. 67)

(Hustedt, Fr., *Pascher's Süsswasserflora*, Heft 10, 1930, p. 414, fig. 791.)

Valve narrow, linear-lanceolate, with slightly convex margins, 26–28 μ long, 4 μ broad; ends produced and slightly capitate; keel punctæ about 11 in 10 μ; striæ very fine.

Habitat.—River Cooum, near Aminjikarai, Madras.

The striæ could not be made out even under very high magnifications. Hence they could not be counted. The general form of the Diatom and its measurements agree with those of *N. microcephala.*

54. *Nitzschia fonticola* Grun.

(Fig. 73)

(Hustedt, Fr., *Pascher's Süsswasserflora*, Heft 10, 1930, p. 415, fig. 800.)

Valve linear, with parallel sides, suddenly tapering at the ends, 22–30 μ long, 4–5 μ broad; ends rostrate; keel punctæ 10 in 10 μ; striæ about 35 in 10 μ, fine.

Habitat.—Rain water pool, Triplicane, Madras.

Section Sigmoideæ

55. *Nitzschia sigma* (Kütz.) W. Sm.

(Fig. 72)

(Hustedt, Fr., *Pascher's Süsswasserflora*, Heft 10, 1930, p. 420, fig. 813, Schmidt, A., *Atlas*, pl. 336, figs. 1–6.)

Valve sigmoid, with rounded ends, 50–60 μ long, 6–7 μ broad; keel punctæ 8 in 10 μ, interrupted in the middle; striæ fine.

Habitat.—River Cooum, near Aminjikarai, Madras.

Family SURIRELLACEÆ

Subfamily: SURIRELLOIDEÆ

Genus *Surirella* Turpin, 1828

56. *Surirella linearis* W. Sm.

(Fig. 75)

(Hustedt, Fr., *Pascher's Süsswasserflora*, Heft 10, 1930, p. 434, figs. 837, 838.)

Valve linear-elliptic, with rounded ends, 60–85 μ long, 20–22 μ broad; central space wide; costæ broad, about 35 in 100 μ.

Habitat.—Irrigation tank, Vandalur.

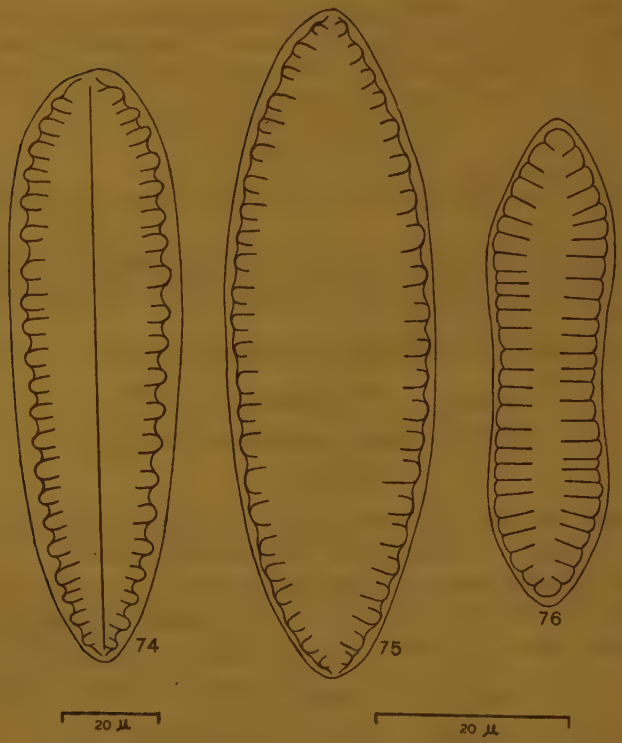
57. *Surirella robusta* Ehr. var. *splendida* (Ehr.) V. H.

(Fig. 74)

(Hustedt, Fr., *Pascher's Süsswasserflora*, Heft 10, 1930, p. 437, figs. 851, 852.)

Valve linear-elliptic, with rounded ends, slightly tapering towards one end, 100–120 μ long, 30–32 μ broad; central space wide; costæ broad, about 20 in 100 μ.

Habitat.—Paddy field, Mangalore; Irrigation tank, Vandalur.



FIGS. 74–76. Fig. 74. *Surirella robusta* Ehr. var. *splendida* (Ehr.) V. H. Fig. 75. *Surirella linearis* W. Sm. Fig. 76. *Surirella angustata* Kütz. var. *constricta* Hust.

58. *Surirella angustata* Kütz. var. *constricta* Hust.

(Fig. 76)

(Hustedt, Fr., *Pascher's Süsswasserflora*, Heft 10, 1930, p. 435.)

Valve linear-elliptic, constricted in the middle, tapering towards both ends, 30–35 μ long, 10 μ broad; ends subacute; central space narrow; striæ about 10 in 10 μ.

Habitat.—Irrigation tank, Vandalur.

The type collection and slides relating to the new species, varieties and forms described in this paper are lodged in the Department of Botany, Presidency College, Madras. The type collection numbers of these species, varieties and forms are as follows: *Fragilaria capucina* Desmaziers var. *courtallensis* var. nov., No. 151; *Caloneis schumanniana* (Grun.) Cleve var. *biconstricta* Grun. f. *interrupta* f. nov., No. 7; *Anomœoneis rhomboidea* spec. nov., No. 48; f. *minor* f. nov., No. 48; *Navicula cuspidata* Kütz. f. *indica* f. nov., No. 18; *N. spicula* (Dickie) Cleve var. *pulneyensis* var. nov., No. 103; *Cymbella ventricosa* Kütz.

var. *depressa* var. nov., No. 3; *Gomphonema macropunctatum* spec. nov., No. 8; *G. abbreviatum* Kütz. f. *minor* f. nov., No. 102; var. *pulneyensis* var. nov., No. 101.

The writer wishes to express his deep sense of gratitude to Prof. M. O. P. Iyengar for his valuable guidance throughout the course of the study and in the preparation of this paper and to Rev. Fr. H. Santapau, for kindly furnishing the Latin diagnosis of new species. A part of the work was done at the Botany Laboratory of the University of Madras during 1942–43. The writer wishes to thank the University authorities for the grant of a studentship during this period.

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SEASONAL VARIATION IN FOLIAR COMPOSITION OF SOME INDIAN FOREST TREES

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(Received for publication on March 10, 1954)

Foliar analysis as a guide in plant nutrition, crop yield, soil fertility and fertilizer-treatment studies of soil is extensively employed in agricultural research in Western countries (Burkhart, 1941; Chapman, 1941; Davies, 1940; Gilbert and Smith, 1929; Hester, 1941; McCollam, 1944; Moser, 1941, 1941 *a* and Scarseth, 1941, 1943). Besides the analysis of green plants, sometimes the analysis of the soil and subsoil are also undertaken. Lundegårdh's (1934 and 1938) triple analysis method for a complete chemico-physiological test of the soil includes the plant, soil and the subsoil, as "in some instances the ash analysis alone gives enough information; in most instances ash analysis plus analysis of the surface layer of the soil will be sufficient; and in still other instances ash analysis, analysis of the surface soil, and analysis of the subsoil are needed".

In subsequent work it was found that the analysis of the surface soil and subsoil could be dispensed with for the additional information provided by these tests was not of any special value than that obtained by analysis of plant alone. Moreover, Mitchell (1939) and Lundegårdh (1941) have drawn attention to the fact that plant analysis makes full allowance for the extent to which plant roots penetrate different soil horizons, whereas this can hardly be done in a technique of soil analysis alone (Goodall and Gregory, 1947, p. 116).

The analysis of the soil by means of plants has been successfully done by Halle (1905), Gilbert and Smith (1929), etc. Thomas (1934, 1937, 1938, 1938 *a*) and Thomas and Mack (1940, 1941, 1943, 1944) in a series of papers have described in detail the technique, application, limitations and results of foliar diagnosis in agriculture and horticulture. Recently Lundegårdh and Mitchell (1951) have fully reviewed the available information on the subject.

Wallace (1943) has developed methods for diagnosing mineral deficiencies in fruit trees by foliar analysis, and Chapman and Brown (1943) have further demonstrated the use of this method in estimating fertility needs of citrus trees.

Although foliar analysis as a tool in soil fertility studies and other related topics is now well advanced in agriculture and horticulture, it has hardly been applied to problems of forestry. Drosdoff (1943) has recently determined fertilizer needs of the tung oil tree by foliar analysis and extensive survey of the available literature by Goodall and

Gregory (1947) seems to suggest that foliar analysis as an ecological method in soil fertility, forest reproduction and plant distribution investigations may lead to useful results. The studies by Mitchell (1936) on conifers have shown that "much valuable information regarding tree nutrition and the chemical aspects of site quality can be obtained from leaf analysis" (Lundegårdh and Mitchell, 1951).

Some triple analysis studies by Puri and Gupta in some forests of India (1950, 1951) and foliar and surface soil studies by Puri (1950) in English forests have provided confirmatory evidence in successional studies. The data for foliar ash, Ca, N, C and C/N of a few tree species from temperate and deciduous forests have given additional information on soil conditions. As most of our forest reproduction problems are tackled by changing soil conditions and altering successional development of a plant community, it is considered that foliar analysis may yield data of value in guiding our regeneration techniques.

The technique of leaf analysis is not fully developed for forest trees and before extending this work to different types of Indian forests it was thought advisable to see if differences in foliar constituents are specific in nature and whether they show marked seasonal variations in one and the same tree. The latter study is expected to indicate the best time for sampling the various species for analysis.

European and American data compiled by Lutz and Chandler (1946) show that there is a good deal of difference in foliar constituents of different species and these differences are specific in nature. Further both ash and Ca content increase and N decreases in most temperate forest tree species with increasing age. The best time for sampling these species is just before the starting of yellowing in leaves. There are no data available for Indian forests and as the growth of plants in tropical climates is somewhat different from that in temperate regions, it is risky to apply the knowledge of temperate plants to the study of tropical species without a critical study (Champion and Trevor, 1938; Champion and Griffith, 1947). In addition, basic data for tropical silviculture are greatly needed to-day for the study of economic problems in forestry.

The following 10 forest species of conifers and broad-leaved trees growing in the plantations at New Forest, Dehra Dun, were investigated.

1. *Pinus longifolia*
2. *Adina cordifolia*
3. *Shorea robusta*
4. *Eugenia jambolana*
5. *Terminalia arjuna*
6. *Terminalia tomentosa*
7. *Tectona grandis*
8. *Ougeinia dalbergioides*
9. *Cedrela toona*
10. *Dalbergia sissoo*

The broad-leaved species are arranged according to the known phenological behaviour; thus evergreen or semi-evergreen species are at the top and deciduous types are last in the list, which is headed by a conifer.

The age of the trees sampled was 20–25 years at the beginning of the experiment. 4–5 well-grown healthy trees of each species were marked at the beginning of the experiment and leaves were collected from the bottom of the crown at weekly intervals, on every Monday. Leaves from all trees of the same species were mixed, air dried, powdered in a mill and sieved for ashing. The ashing was done in a muffle furnace at 800° C. and Ca, Mg and N were determined on duplicate samples by the usual methods (Loomis and Shull, 1937). The results are expressed as percentage of dry matter and the data are graphically presented in Figs. 2–5. Mean values for the various constituents studied are given in Table I below:—

TABLE I

Foliar constituents, percentage of dry material, mean for the year

	Ash	Ca	Mg	N
Pinus longifolia ..	3·35	1·41	0·24	1·28
Adina cordifolia ..	6·53	1·83	0·32	2·02
Shorea robusta ..	4·35	0·84	0·32	1·64
Eugenia jambolana ..	6·47	2·36	0·70	1·28
Terminalia arjuna ..	7·23	2·86	0·48	1·36
Terminalia tomentosa ..	8·38	3·34	0·58	1·72
Tectona grandis ..	8·98	2·61	0·36	1·51
Ougeinia dalbergioides ..	7·89	2·62	0·45	2·11
Cedrela toona ..	10·86	4·23	0·60	2·24
Dalbergia sissoo ..	9·06	3·45	0·76	2·67

New Forest is situated at an altitude of 2,200 feet above sea level in the Dun valley between the outer Himalayas on the N.-E. and the upper Siwaliks on the S.-W. The site is an old agricultural land formed of the Siwalik clay overlying, boulder-conglomerate rock at depths varying from 6–8 feet. The clay is non-calcareous, ferruginous and with addition of organic matter forms fertile forest soils on the surface. The plantations were raised on this soil between 1925–26. Chemical analysis of the soil under four types of plantations from where plants used in this investigation were collected are presented elsewhere (Puri and Prem Nath, 1952), and physical analyses of the soil were done by Dr. R. S. Gupta at 5 yearly intervals.

Climatically, the locality is characterised by monsoon rainfall of 80–90 inches annually, the greater amount falling during the months of July-September. There is some rainfall during the months of December–February. Summer maximum temperatures are 80–85° F. and in winter a minimum of 45–48° F. is sometimes found, with a ground frost. Humidity is fairly high throughout the year, except during the months of April–May, when it is dry and hot. Deciduous species shed their leaves during the months of January–March in this area.

Of all the foliar constituents Ca and N have greater importance ecologically in forest studies. In agricultural studies, however, a ratio of N: P: K and Ca: Mg are usually determined. In forest soils the fertility usually is a good index of soil calcium and nitrate nitrogen. In this investigation, therefore, attention is directed to the variation of these two substances only.

Ash.—Figure 1 will show that in *Pinus longifolia* the percentage of ash increases in new shoots during April–May and again in June–July and November–December. It is more or less constant in July–November and then between January–March. Among the evergreen or semi-evergreen broad-leaved species there is a definite, though small, increase in percentage of ash from leaf-bud opening to leaf-fall stage. In *Shorea robusta* there is a slight increase in March–April, June–July, August, October and December, and a more or less similar trend in the seasonal variation of ash is found in *Eugenia jambolana.*

In *Adina cordifolia* there is a high increase in ash content during April and May–June and a small rise during the middle of December and February. During August–December ash content in this species seems to be more or less constant.

In *Terminalia arjuna*, *Terminalia tomentosa*, and *Tectona grandis* ash percentage shows a decrease from leaf-bud opening to leaf-fall stage, though there are, in between, periods of high content of ash, particularly in *Terminalia tomentosa.*

In *Cedrela toona* and *Ougeinia dalbergioides* there is a definite increase in percentage of ash from leaf-bud opening to the leaf-fall stage.

The results for Indian species investigated do not show any uniformity in variation of ash content in leaves with age, though the data for 9 hardwood species from America given by Lutz and Chandler (1946, p. 150) show an increase in ash content with age. It may be stated that American species referred to above were all deciduous, and similar increase in ash content with age is found in most of the deciduous species investigated; but semi-deciduous and evergreen species do not conform to this trend. It is difficult to explain this in the present stage of our knowledge. However, it may be pointed out that the species investigated have their natural homes in different geographical regions of India and some of these do not belong to the region where they have been cultivated for experimental purposes. In their own habitat they may probably exhibit a uniform trend in foliar ash which may be different from species of other regions. However, this is merely a guess.

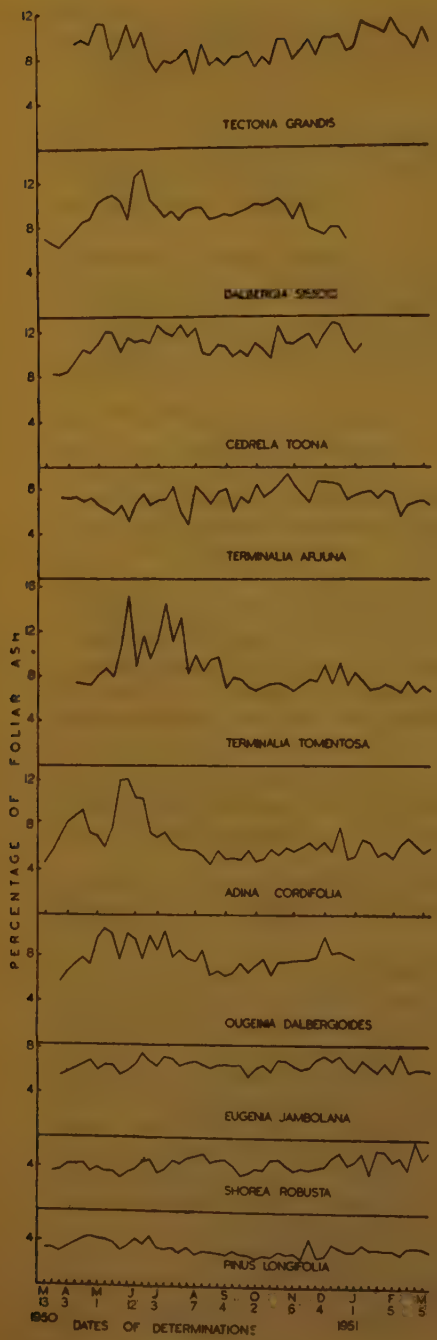

FIG. 1. The seasonal variations of foliar ash in ten species of forest trees.

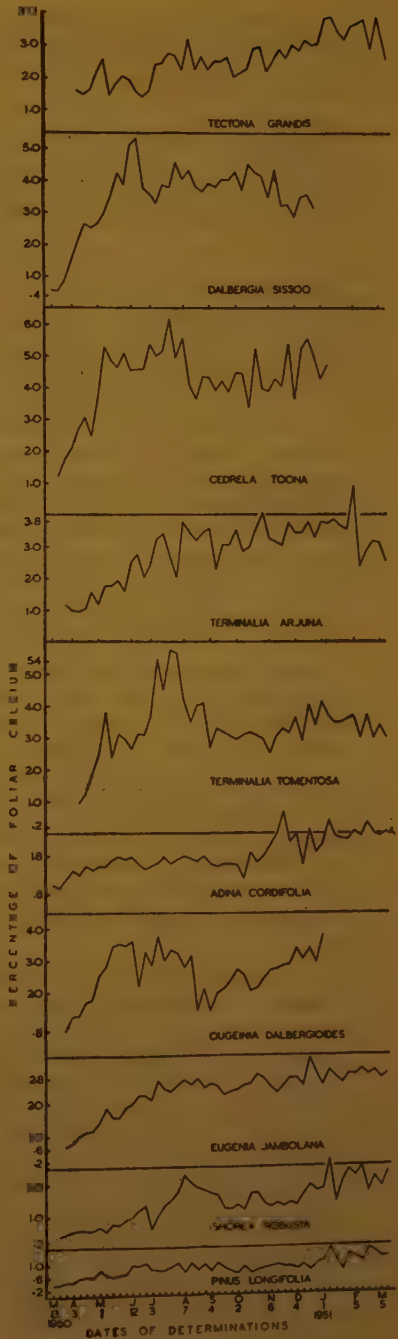

FIG. 2. The seasonal variation of foliar Ca in ten species of forest trees.

These results show clearly that the ash content of leaves of different species, even when planted under uniform conditions of soil and climate shows a large amount of variation, which may be specific in nature. On the whole, conifer and evergreen broad-leaved species that are towards the top in the Table are low in ash constitutents; but higher amounts are found in deciduous species. The foliar ash may thus have some relationship with phenological behaviour of different species.

Calcium.—Unlike ash, calcium content in leaves of all the species investigated shows an increase from leaf-bud opening to leaf-fall (Fig. 2). In the chir pine the increase with age is not conspicuous, but in broad-leaved species the increase is of a high degree. These results thus agree with those of European (Mitchell, 1936; Olsen, 1948; Tamm, 1951) and American workers (*see* Lutz and Chandler, *loc. cit.*). Although the increase is not uniform in the Indian species investigated, it seems that if leaves are collected for calcium determinations in different species at or near the time of maturity of the leaves results may

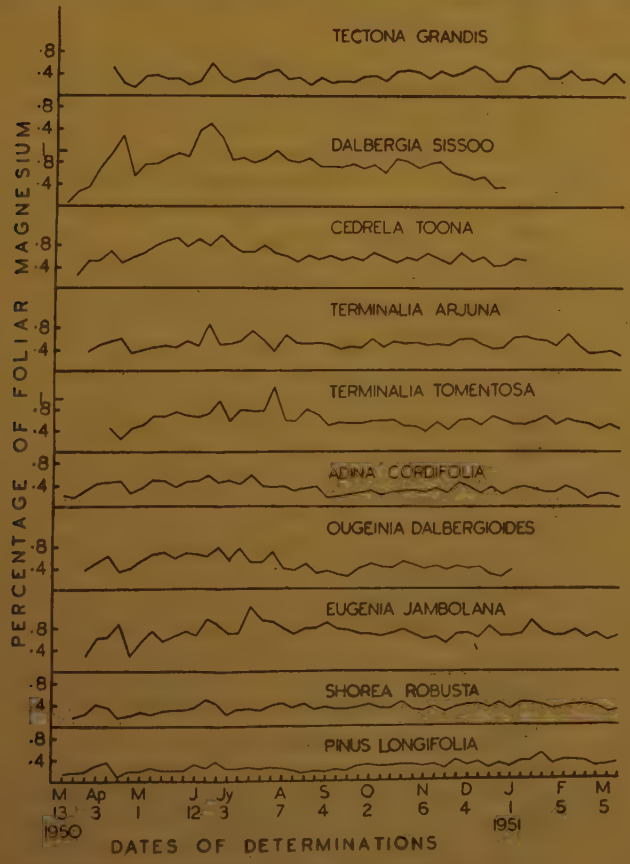

FIG. 3. The seasonal variations of foliar Mg in ten species of forest trees.

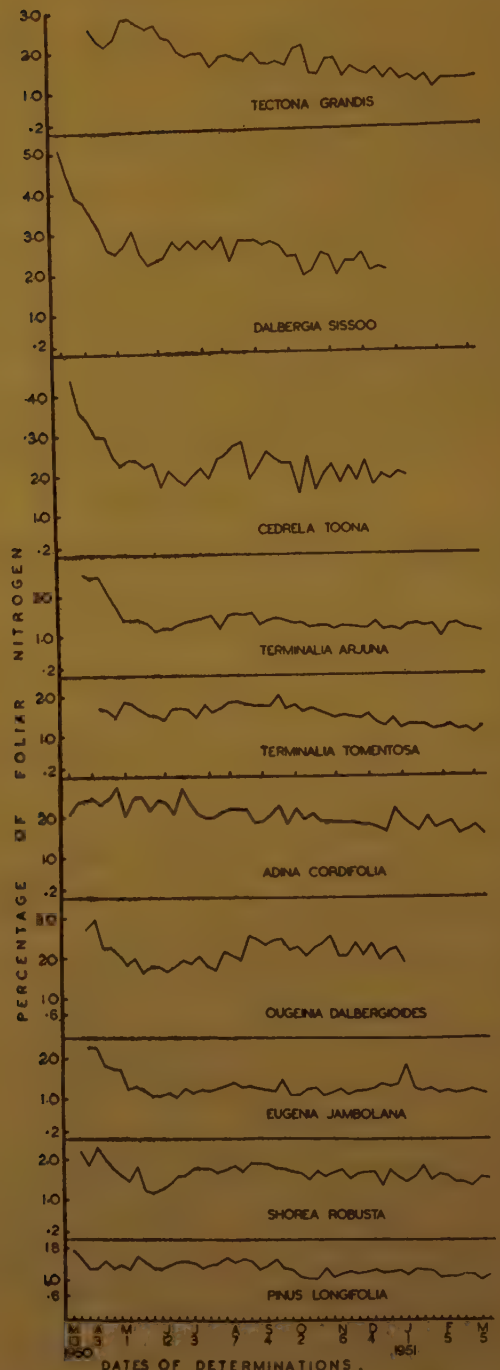

FIG. 4. The seasonal variations of foliar N in ten species of forest trees.

be comparable. Differences in Ca content are specific. As the species are growing on a uniform type of soil, differences in foliar Ca may indicate that absorption trends in evergreen and deciduous species are different.

Most of the evergreen species investigated have low calcium content and highest values were found in deciduous species which may again show some relationship with phenological behaviour of the species. Sal with the minimum foliar calcium content is probably a non-exacting species, as it does not flourish on calcareous soils.

Of the deciduous species with high foliar Ca content, teak, sissoo and toon occur on alluvial soils which are rich in Ca salts and also affect lime sufficient localities. These species are most probably calcicoles.

Magnesium.—Magnesium does not follow a uniform trend of variations in all the species investigated (Fig. 3). In some species there is a small increase from leaf-bud opening to leaf-fall, especially in evergreen species, while in others there is a slight decrease. In most species, however, there is a small rise from leaf-bud opening to July or August, after which the percentage of magnesium in most species falls, becoming more or less constant over a number of months and finally in one or two cases there is an appreciable fall (*e.g.*, in *Dalbergia sissoo*). Except for *Eugenia*, other evergreen species have lower amounts of foliar Mg and its content in deciduous species is generally high. It is not possible, however, to explain the behaviour of Mg in this respect.

Nitrogen.—Unlike calcium, the percentage of nitrogen falls considerably in all the species investigated from leaf-bud opening to leaf-fall (Fig. 4). In the chir pine and other evergreen or semi-evergreen broad-leaved species the fall is not rapid, but in deciduous species decrease in nitrogen content after the month of April-May is very rapid. In evergreen species the fall is followed by a more or less constant percentage till December–January or February when there is a small rise in nitrogen content, again followed by a fall. Comparing the graphs of evergreen and pronounced deciduous species it seems that fall in nitrogen content in the latter is rapid.

The results for variation in nitrogen content of Indian species are in agreement with European and American works, referred to above. Although there does not exist a complete uniformity in the variations with age in all the species investigated, it appears that for comparative purposes mature leaves give better results. Excepting *Adina cordifolia*, the percentage of foliar nitrogen in the evergreen species, on the whole, is low and higher values are obtained in the deciduous types.

Leaves of sal have fair amounts of N, but it is low in teak. The absence of any profuse ground flora in teak forests may be due in part to low nitrogen content of teak litter. However, from this one should not minimise the effect of light, for light intensity has also been shown by some investigators to have the same effect as nitrogen content on the activation of forest soil.

Incidentally, the N variation data can be used in selecting N-rich species and the time when these should be sampled to get the maximum amount of Nitrogen for protein synthesis.

Discussion

The study of seasonal variations in foliar ash, Ca, Mg and N of 10 Indian forest trees growing in New Forest shows that the amount of each constituent is specific in nature. There is not much uniformity in variational trends in ash content of all the species, but deciduous species show an increase with age like European and American species.

There is a marked increase with age in Ca content in all the species studied, both evergreen and deciduous, which agrees with results of European and American investigations. Nitrogen shows a general decrease with age in all the species, which also agrees with previous work in other regions. In the present stage of our knowledge of tree physiology it is not possible to give an explanation for the week to week variations in contents of various constituents. Tamm (1951) has provided interesting data for some Swedish species showing that both minerals and nutrients are leached out of the growing leaves during rain. While some such effect of rain may be discernible in some of the deciduous species studied, this point needs a closer investigation for we have a long and continuous period of rainfall, followed by a dry spell in this country. In some of the Indian species investigated there is a distinct decrease in Ca content during July-September, which are rainy months and again in January–February when also some rain falls. But in other species there is an increase in this period. A similar variation is seen in N content, but a more detailed study of one or two species from this view-point is necessary before one can make a definite statement.

The data for Ca and N seem to show that in deciduous species an increase in Ca and decrease in nitrogen content seem to run parallel with whatever factors are responsible for yellowing of leaves and their fall. In evergreen species in which leaf-fall is not so distinct as in deciduous trees increase in Ca and decrease in nitrogen towards the leaf-fall period is not so pronounced. It seems that in addition to external factors internal differences in Ca and nitrogen content in leaves are closely associated with phenological behaviour of plants.

Another fact of considerable interest with regard to Ca variation is that just before leaf-fall Ca content does not increase in leaves but there is a slight decrease in most species from the earlier maximum. This has been observed by European and American workers also and as suggested by them it may be due to the migration of Ca into the shoots before the leaf-falls. A detailed analysis of shoots at different periods during their growth and of attached leaves may yield interesting results. It is believed in some quarters that as trees shed their leaves annually, no harm will be done to tree growth if trees are regularly lopped. The data here presented, however, seem to show that at natural leaf-fall stage some Ca migrates to the branches and is thus retained by the plant but lopping will doubtless deprive the tree of Ca reserve.

Although, it has not been possible to give a uniform time of sampling for comparable Ca and N studies in all Indian forest trees investigated, the data seem to show that for deciduous species samples may be collected just before leaf-fall and in evergreen species during the months of January–February which is more or less comparable to leaf-fall of deciduous species. Another difficulty that is likely to arise is that one and the same species throughout its zone of distribution sheds leaves at different times of the year and many have intervals of one or two months in different places. A uniform date of sampling is therefore out of question for Indian trees especially for those that have a wide range of distribution.

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SOIL CLIMATE OF SOME INDIAN FORESTS

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Soil climate is defined by Koloskov (1946) as "the sum total of the diurnal and annual cyclic phenomenon prevailing in the soil. These phenomena influence the life and productivity of the soil and they are dependent on the outside climate, soil substratum and the effect of the human on the soil and its cover". Joffe (1949) considers that "these studies are nothing more than studies on soil temperature, moisture and aeration". In this paper I have followed these two authors and have determined the soil moisture, organic matter, relative humidity (soil moisture/organic matter, *see* Crump, 1913), temperature, pH and exchangeable calcium as chief elements of soil climate. As micro-climate above the soil shows variation with height from the ground, variations in the soil climate are similarly observed with depth, at any one time. But the exact significance in plant growth of variations in soil climate are not adequately known. These probably determine the periodicity, or aspect, of ground flora vegetation, including the seedling growth, and influence the availability and absorption of water and nutrients by plants. These studies are, therefore, of great silvicultural interest.

Our knowledge of both the soil climate and micro-climate above the soil for Indian forests is very meagre, indeed. In the revised edition of the "Manual of General Silviculture of India", Champion and Griffith (1947) considered that local failure in natural regeneration of forests is due to purely local unfavourable conditions of micro-climate and soil climate, and that such information will be of great use in evolving the most suitable regeneration technique for Indian species.

For the exploratory study of soil climate reported in this paper pits were dug, one each, in the plantations of chir pine (*Pinus longifolia*), sal (*Shorea robusta*), teak (*Tectona grandis*) and in a grassy area in the open. Samples of soil for pH, moisture content, loss on ignition and calcium determinations were collected every Monday from the depths of 0″, 6″, 18″, 24″, 36″, 48″, 60″, 72″ from each of the four pits.

The small portion of the wall, from where samples were to be collected, was freshly deepened all along its length and breadth to a depth of 8 to 12″ on every Monday and from the freshly exposed surface nearly ¼ lb. of soil sample was collected and quickly brought to the laboratory for determination of soil moisture. Along with this, soil temperature was determined with a centigrade thermometer, which was carefully shielded from the direct insolation of the sun and

inserted into a freshly made hole in the wall of the profile at various depths. The temperatures were read off after the mercury had become constant and the thermometer was still in contact with the soil. These field investigations were completed between 10 A.M. and 11–30 A.M. on most of the days, but in a few cases on rainy days the work had to be continued till 12 noon. The collection of samples from all the depths was discontinued after some weeks as we could not cope with the work.

The data presented here were obtained for the following four seasons:—

1. Rainless dry summer period from 3–4–1950 to 22–5–1950.
2. Rainy summer period from 7–8–1950 to 11–9–1950.
3. Rainless winter period from 27–11–1950 to 18–12–1950.
4. Rainy winter period from 25–12–1950 to 5–2–1951.

The determinations were made by the following methods:—

1. Moisture content is the constant weight of the soil attained by keeping the sample at temperature of 100° C. in a gas oven.
2. Organic matter is the loss on ignition obtained by igniting moisture-free soil to constant weight on bunsen burners.
3. Relative humidity of the soil is the ratio of moisture content/ loss on ignition, as suggested by Crump (1913) and adopted by Pearsall (1938) and Puri (1950) in soil studies.
4. pH was determined electrometrically by shaking one part of the soil with five parts of water using glass electrode, with Beckman dry battery pH meter.
5. Exchangeable calcium was determined by the usual oxalate method suggested by Loomis and Shull (1937) and adopted by us (1951) in earlier studies.
6. Temperature of the soil was determined, as already noted, by centigrade thermometer, shaded from direct insolation of the sun.

As the soil profiles have to be dug and samples collected for the determination of other elements of the soil climate the measurement of temperature by this method was found convenient for complete studies. This method was suggested by Troup (1926) and earlier used by Leather (1915) in determining seasonal variations in temperature of agricultural soils. Geiger (1927, 1950) has also used centigrade thermometer in some of his early micro-climatic studies. In fact, all early work in Scandinavia, Germany and other parts of Europe on soil temperatures was done by mercury thermometers (Vaartaja, 1949), and the use of thermocouple is only recent. Thornthwaite (1948) has also used centigrade thermometers in some early macro-climatic studies, though thermocouples are now being put in use. Some workers used earth thermometers, which are not different from the common thermometers.

Although the absolute correctness of the temperature data cannot be guaranteed the mercury thermometer figures are given here for merely comparative purposes. A thermocouple installation for measuring soil temperatures at various depths in the open was set up and the results obtained for rainless summer during 1951 show that temperature becomes constant at about 42″ depth. Our data for the corresponding period during 1950 for the pits in the sal and teak plantations show constant temperatures at the depth of 48″, and more or less constant temperatures in the grassland and the chir pine pits at about the same depth were found. The thermocouple and earth thermometers will be used in subsequent studies of diurnal, seasonal and spatial variations in soil temperatures.

The detailed data for soil climate are deposited in the Ecology laboratory and can be readily had for examination.

A short account of the site of the experiment is given as under:—

New Forest is situated in the Dehra Dun valley at an altitude of about 2,200′ above sea level. The climate is monsoonic with an average of 80 to 90″ of annual rainfall, of which nearly 4/5 falls during the rainy summer. During winter up to 5″ may fall; the rest of the rainfall being distributed in the remaining months.

The soil at the New Forest, geologically, comprises of the Siwalik clay overlying conglomerate. The depth of the clay in the area is between 6 and 9′ and except in the chir pine block conglomerate layer nowhere seems to come within 6 feet of the surface; so most of the work was done in the clayey soil, which is non-calcareous and ferruginous. The area was an agricultural land till recently, when it was taken over in 1925–26 and planted with forest trees. The three plantations are nearly 25–26 years old and the grassy area was cleared only a few years ago of planted trees and temporarily made available for this experiment.

The land slopes gently towards S.W. with a gradient of roughly 1 in 50 feet. The chir pine plot on the N.E. is at the top and the teak plantation is at the lower level. The other two plots are in the middle.

pH

The study of seasonal and spatial variations in pH of the soil has attracted the attention of a number of ecologists, but little work seems to have been done to see variations of pH with depth. Baker and Clapham (1939) working on three types of woodland soils in England found interesting monthly and annual variations in soil reaction. They correlated annual variations in pH with annual rainfall and found that "the acidity of gravels is increased but that of clays and loams decreased during years of low rainfall." Monthly variations in pH were also related to monthly variations in rainfall.

Baver (1929) found a seasonal difference of nearly one pH unit. Feher (1932) found that pH was maximum in winter and minimum in summer in forest, agricultural and pasture soils. Swanback and

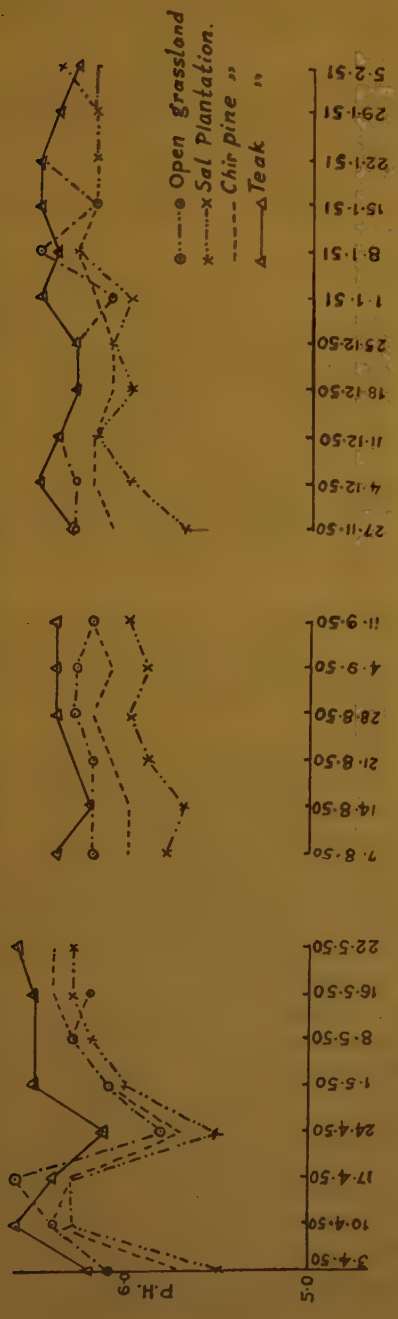


FIG. 1. Seasonal variations of pH value in the four vegetation types.

Morgan (1930) found maximum pH during wet season and minimum in dry weather. Loddesol (1932) also found seasonal variations in pH.

pH of the soil determines the absorption of minerals and nutrients in higher plants (Arnon, Fratzke, Johnson, 1942; Arnon and Johnson, 1942); and seedlings of trees have a definite pH tolerance range (Chapman, 1941; Puri, 1950; Pearsall, 1938; Olsen, 1930). The effect of pH on the growth of plants in early stages of their growth was studied for citrus by Guest and Chapman (1942) and Hayward and Blair (1942).

Recently, detailed work on seasonal and spatial variations of pH of some Australian soils in relation to a disease in sheep was conducted (Downer and Beckwith, 1951; Raupach, 1951). Hester and Shelton (1933) have used pH data in making recommendations for lime application in soils and the role of pH in mineral nutrition of plants (Hoagland, 1944) is now greatly appreciated. Small (1946) has given a useful summary of known information on pH and plants.

In the data presented here both seasonal and with depth variations in pH were found. Vegetational cover seems to exercise some influence on the pH value of the soil; however, the trend in seasonal variations in all the four types of vegetation is on the whole, more or less similar.

For ascertaining the seasonal variations in pH the data for all depths was added up and means for each pit are plotted in Fig. 2. For giving a clear relationship of pH variation during each period with depth, data for all dates in a period was added up and means plotted in Fig. 3.

It will be seen (Fig. 1) that pH of the soil during the dry period (from 3–4–1950 to 22–5–1950) is the lowest under the sal plantation, while highest values were obtained under the teak. Soils in the chir pine and open grassland showed intermediate pH values. After 3–4–1950, pH became higher in all the pits, then it showed a fall in teak and chir pine, but a slight rise in the open grassy area was followed by a sudden fall. After 24–4–1950 there was a gradual increase in pH value in all the pits, excepting in the open grassland, on which a slight decrease was seen after 8–5–1950.

The variation in soil reaction with depth during this period shows that in teak soil, pH increases from 0″ to 6″ and then it is constant up to 36″ (Fig. 2). It again rises slightly, and after 48″, pH becomes constant. In sal plantation, however, pH decreases from 0″ to 24″, after which there is a slight rise and at 36″ to 60″ it is constant. Below 60″ there is a slight fall in pH value. In the chir pine plantation and in the open grassy area, pH decreases from 0″ to 18″ and becomes constant between 18″ and 36″. Below 36″ in the chir pine block, pH rises and then becomes constant between 48″ and 72″. But in the open pH falls a little below 36″ and then rises at 48″ to its original value.

In the rainy period between 7–8–1950 to 11–9–1950, pH of the soil under sal is the lowest and under teak highest values are attained.

Graph No. 2. Showing relation between mean pH value and the various depths

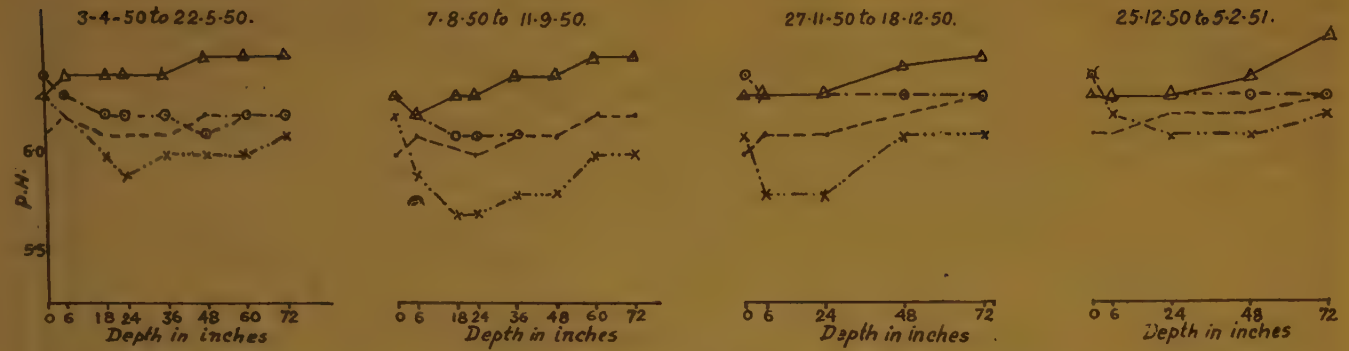


FIG. 2. Relationship of pH value with various depths in the soil profile under the four vegetation types.

Grassland in the open registered pH value lower than the teak and the next lower figures are found in the chir pine Block. Both in the teak and the sal, pH value of the soil falls from 7–8–1950 to 14–8–1950. After that it shows a rise in all the four pits, till 28–8–1950. In the chir pine and the sal Blocks, pH falls again and then rises to its original value. In the teak, it is constant till 11–9–1950. But in the open grassy area it shows a slight fall after 4–9–1950.

As seen in Fig. 2, pH of the soil in the teak plantation during the monsoon rainy period shows an increase with depth. In the sal plantation, however, pH falls from 0″ to 18″ and then rises by steps below 24″; and below 36″ becomes more or less constant. In the open grassy area pH falls as in the sal plantation, but the fall is gentle; and from 18″ to 36″ pH is constant. Due to heavy rain the pit was full with water below 36″ and soil samples could not be collected. In the chir pine area pH of the soil shows a slight increase from 0″ to 6″, then a decrease from 18″ to 24″, followed by an increase in steps, similar to that found in the sal plantation.

During the winter period from 27–11–1951 to 5–2–1950, pH value of the soil under sal continues to remain the lowest, but in the teak the highest values of the four types studied are found. In all the four pits there was a more or less rhythmic increase and decrease in pH.

For the purpose of examining variations in soil reaction with depth this period has been subdivided into two. The first sub-period from 27–11–1950 to 18–12–1950 is called the rainless winter; and the other from 25–12–1950 to 5–2–1951 is termed as rainy winter when there was a little rainfall on some days.

In the rainless winter period variation in pH in the sal, teak and chir pine plantations with depth is of the same type as seen in the preceding rainy summer. In the open grassy area, however, pH showed a decrease from 0″ to 6″, and then was constant throughout the profile. Similar variations of soil reaction with depth in grassy area is seen during the rainy winter period. In the sal plantation, pH showed a fall from 0″ to 24″, then it became constant and increased a little below 48″. Except, for a slight increase from 0″ to 24″ in the chir pine area, the pH value below 24″, showed similar variations as is seen in the sal plantation. In the teak area, pH value of the soil is constant up to 24″, below which it increases to the depth of 72″.

Although it is difficult to explain all the seasonal variations in pH in the various sites studied a few general correlations are indicated. On the whole, pH values in all the pits are the lowest during the summer rainy period and highest in the dry summer and winter. These data thus agree in a general way with the conclusions of Baker and Clapham (*loc. cit.*). Soils under sal are more acidic than the chir pine, grassland and teak during all the seasons, and the subsoil has lower values almost throughout the year. On the other hand in teak soil pH values are the highest in all the seasons and subsoil is less acidic. This is interesting and tends to provide further evidence in support of the suggestion (*see* Puri, 1951) that sal is probably a calci-

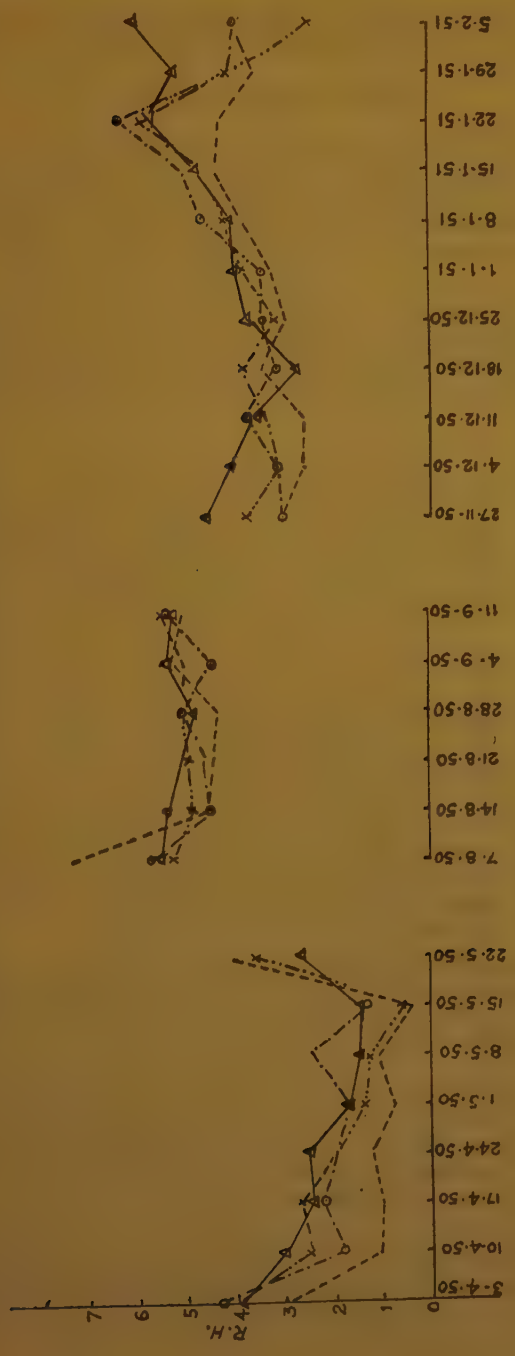


FIG. 3. Seasonal variations of R.H. in the four vegetation types.

fuge and teak a calcicole. The treatments for their regeneration in natural forests should, therefore, be of different types.

Relative Humidity of the Soil

Relative humidity of the soil is represented by the ratio of moisture content to organic matter of the soil. Since organic matter of the soil in a way governs the moisture content of the soil and both are important in plant growth it has been thought better to study R.H. rather than the soil moisture and organic matter, separately.

The importance of soil moisture in plant growth has been investigated by Maximov (1929), Shantz (1925), Livingston and Hawkins (1915); and recently Kramer (1949) has provided an excellent summary of the existing knowledge in this subject. Fundamental studies on the thermodynamics of soil moisture were made by Edlefson and Anderson (1943).

The subject of root development in relation to soil moisture has been studied by Conrad and Veihmeyer (1929), Veihmeyer and Hendrickson (1927, 1938), etc.; and general studies on the relationship of water to photosynthesis (Schneider and Childers, 1941), availability of nutrients (Emmet and Ball, 1933), germination of seeds (Doneen and McGilliorary, 1943) and other life processes in plants (Reiman *et al.*, 1946; Livingston and Hawkins, 1915) have also been made.

Wilson (1941) studied diurnal changes in soil moisture. Such changes in soil moisture, with seasons and depth are important to plant growth in tropical regions; they have, however, not been given sufficient attention. In India seasonal drought is one of the serious factors delimiting plant distribution and growth and with a view to follow the phenomenon of well marked seasonal aspect or periodicity of the ground flora vegetation in this country the studies on seasonal and with-depth variations of soil moisture and organic matter are of fundamental importance. In the data presented here interesting information on the dynamics of soil relative humidity is obtained but their relationship with plant growth is not known.

Seasonal and with-depth variations in soil R.H. were seen. Soil R.H. decreases in all the four areas from 3–4–1950 to 10–4–1950, then it shows a more or less rhythmical variation till 15–5–1950 when it increases again in all the four cases (Fig. 3).

In all the four areas it increases during dry summer from 0″ to 6″ and to 48″ (Fig. 4). The lowest R.H. during this period was in the chir pine area. The teak and the sal plantations had, on the whole, high soil R.H., although on 8–5–1950 it was higher in the open than in the two former plantations.

During the rainy weather, soil R.H. in all the four cases and at all the depths was higher than in the preceding dry period. A small increase from 0″ to 72″ in soil profiles in nearly all the plantations was seen.

Graph No. 4. Showing relation between mean R.H. and the various depths

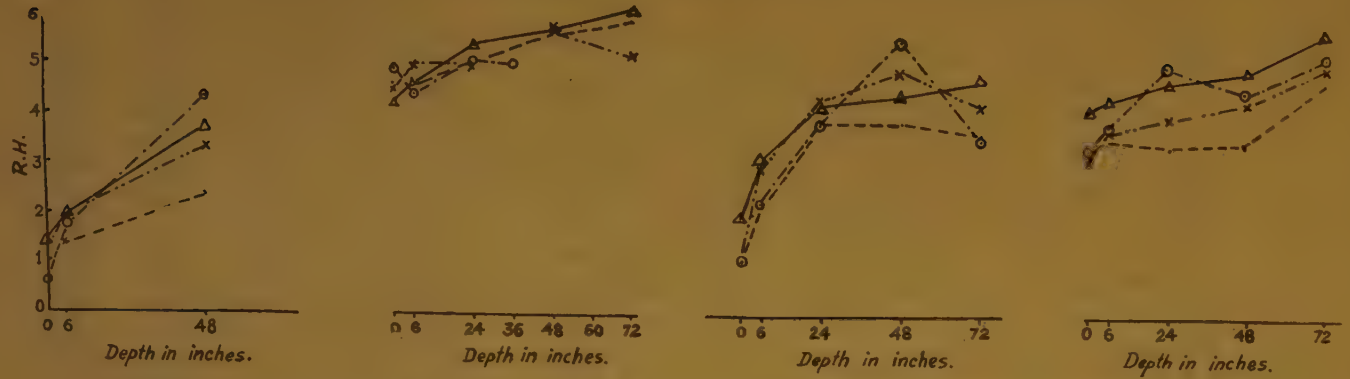


FIG. 4. Relationship of R.H. with various depths in the soil profile under the four vegetation types.

In the winter period, soil R.H. was somewhat lower than in the preceding period and it showed rhythmical variations from 27–11–1950 to 1–1–1951, after which there was a sudden rise in R.H. in the three areas, excepting in the chir pine.

In the rainless winter period, R.H. increases from 0″ to 48″ and below this there was a little difference in the four cases. It showed a slight increase in the teak plantation below 48″, but in the other three areas there was a fall in R.H. In the rainy winter period, soil R.H. on the whole increased with depth in all the four areas, but in the chir pine plantation from 0″ to 48″ there was not a perceptible rise.

Soil R.H. is largely determined by rainfall, temperature, and R.H. of the atmosphere, however, the data show that the effects of vegetation on relative humidity of the soil are no less important.

Some observations on the amount of rainfall reaching the soil in the four areas were made in the summer of 1950. In the open grassy area it was the highest and the next higher rainfall reaching the soil through the canopy of trees was seen in the chir pine area. The rainfall reaching directly to the soil in the teak and sal plantations is somewhat lower than in the other two areas. Temperature of the air in teak and sal is also lower in summer as a result of which there is less loss of water from the soil. It is probably due to this factor that soil R.H. in these plantations during the summer was higher than in the chir pine and grassy areas. It may also be due to different water requirements of trees and ground flora species growing in these plantations.

The seasonal and with-depth variations in soil R.H., on the whole are related to climatic conditions of the area. The small differences in the four pits are due to the vegetal cover of different plants, and also probably due to the different physiological requirements of the species for soil moisture.

Temperature

Temperature is one of the important conditions in the life processes of plants. Brown (1939) showed that chemical composition of grasses depends on this factor and Livingston (1913) showed a relationship between temperature coefficient and plant growth.

The absorption of water in cucumber plants was shown by Schroeder (1939) to be related to root temperature. The movement of the soil moisture is also related to the soil temperature (Buckingham, 1907). Canon (1917) showed that root growth of seedlings is governed by temperature.

Temperature conditions, transpiration in trees (Cameron, 1941; Clements and Martin, 1934) and altitudinal distribution of plants are really the effect of temperature on plant growth (Shreve, 1924; Daubernmire, 1943).

The decomposition of forest litter and the biological circulation of minerals and plant foods are influenced very greatly by suitable temperature.

Graph No. 5. Showing relation between mean temperature in centigrade and dates

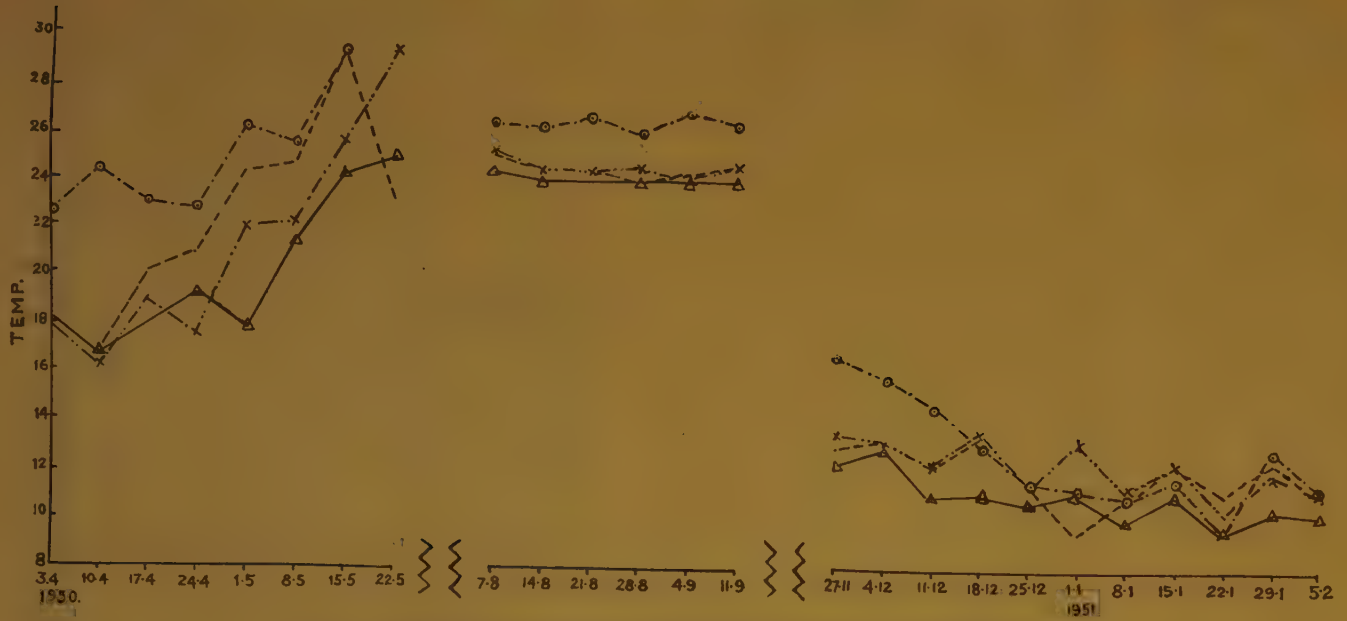
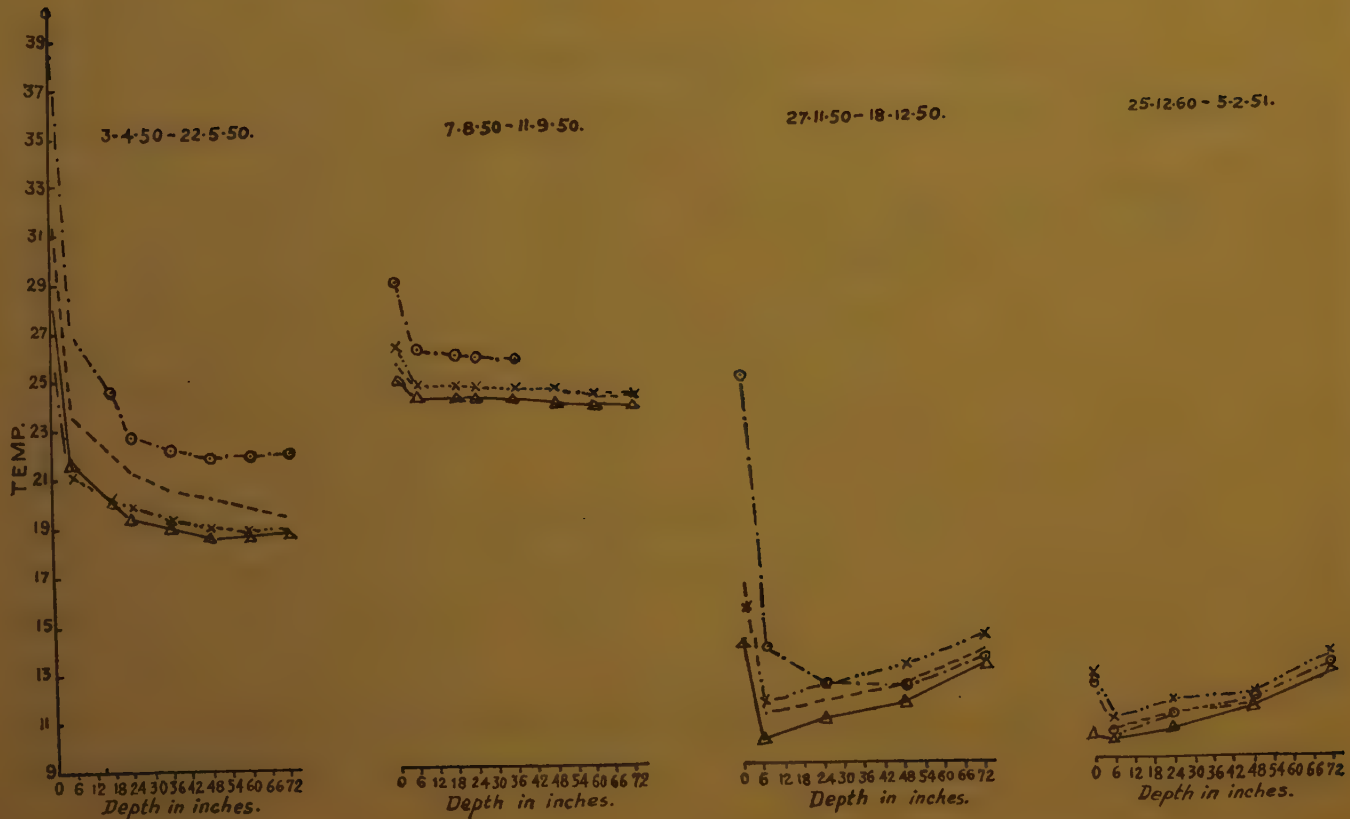


FIG. 5. Seasonal variations of soil temperature in the four vegetation types.

Graph No. 6. Showing relation between temperature in centigrade and depths



On account of the importance of the temperature factor in plant growth studies in atmospheric temperature were made by Frith (1948), Gieger (1927, 1950), Thornthwaite (1948–51) and Ramdas (1933–34). The temperature changes near the surface of the ground and in the soil were also made by these investigators.

Brixton (1924) studied soil temperature of deserts and Vaartaja (1949) of Finnish heaths, with a view to relate plant growth with this factor.

Daily variations in soil and air temperatures (Smith, 1929) and seasonal fluctuations in subsoil temperature (Smith, 1932) are of interest as shown in India by Ramdas and others for agricultural crops. In 1915, Leather studied seasonal changes in soil temperature and attempted to relate this with the growth of agricultural crops. So far as the author is aware no such studies have been made in Indian forests and these should be of interest in silvicultural research.

The data presented here show that during the dry summer period from 3–4–1950 to 25–5–1950, temperature rose in all the areas. As was expected highest temperatures were found in the open and the next highest in the chir pine plantations; in the teak block, temperature was throughout the lowest. However, on 10–4–1950 and 24–4–1950 temperature under the sal plantation was lower than in the teak.

The variations in the soil temperature with regard to depth show a steep fall from 0″ to 6″, then the fall is more or less gradual, uptil 24″. Below 48″ in the teak, sal and grassy areas, temperature becomes more or less constant. In the chir pine, however, it goes on decreasing slightly with the depth.

During the monsoon period the temperature of the soil in all the four areas becomes low and is more or less constant under the teak (Fig. 5). In the other three cases the change is rhythmical. As regards variations with depth there is a decrease in soil temperature from 0″ to 6″, below which it is more or less constant in all the cases (Fig. 6).

In the winter period the temperature becomes low rapidly from 27–11–1950 to 25–12–1950 in the open grassy area, but in the other three cases the fluctuations are rhythmical. Figure 6 will clearly show the bracing effect of vegetation on "soil climate". In the teak area, the temperatures were the lowest.

The variation of temperature with respect to depth for this period (Fig. 6) shows a sudden decrease from 0″ to 6″ and then a gradual increase in the three areas, excepting that in the open.

Soil temperature to a large extent determines the R.H. of the soil. The data of R.H. and temperature of the soil for the dry summer were statistically analysed and curves fitted in Fig. 7. The chief indications are given below:—

1. The trend of the curves fitted is almost the same in the four areas.
2. There is a sudden decrease in soil R.H. with the rise of temperature.

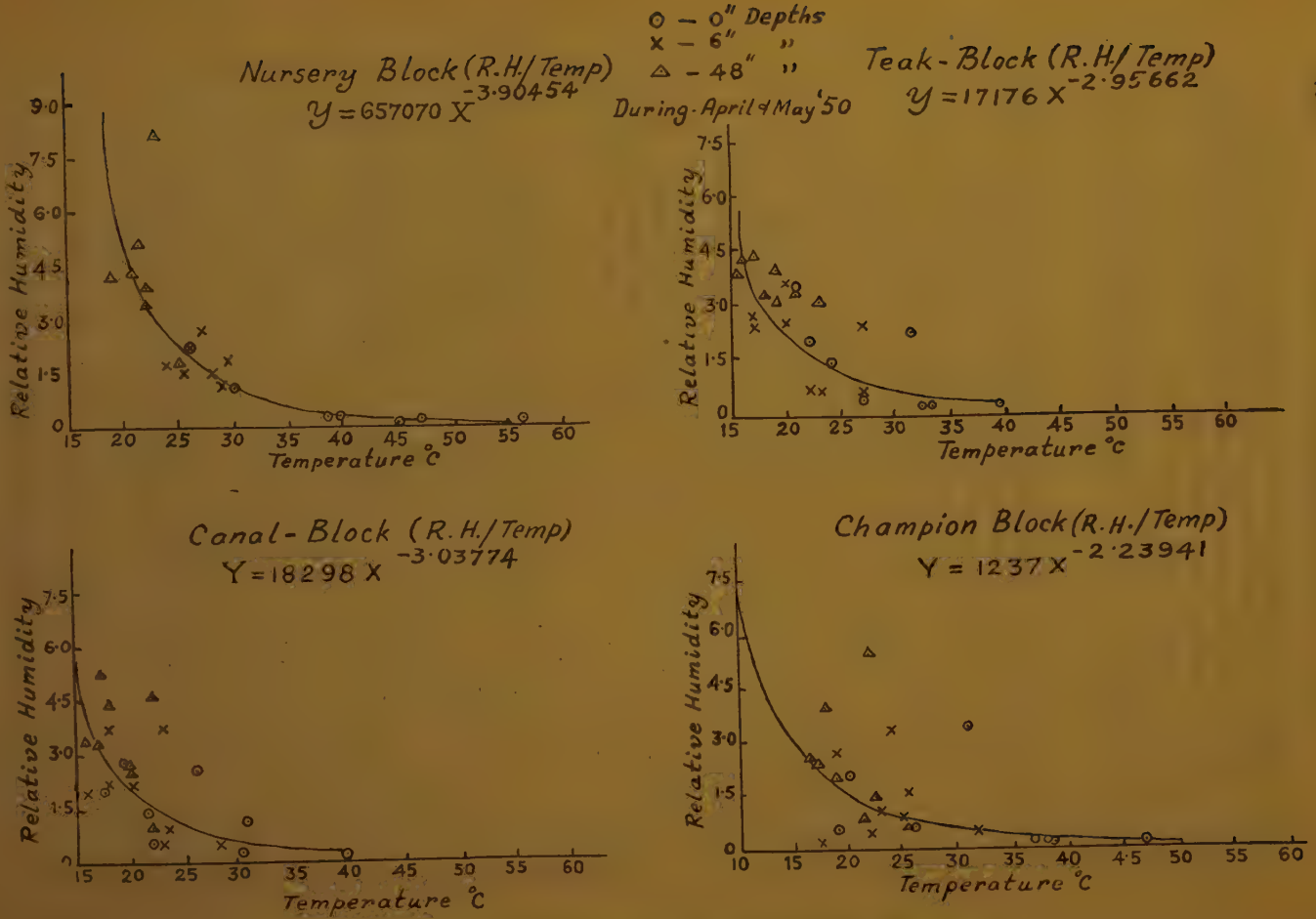


FIG. 7. Relationship of soil temperature and RH in the four vegetation types.

Graph No. 8. Showing relation between mean exchange calcium and dates of observation

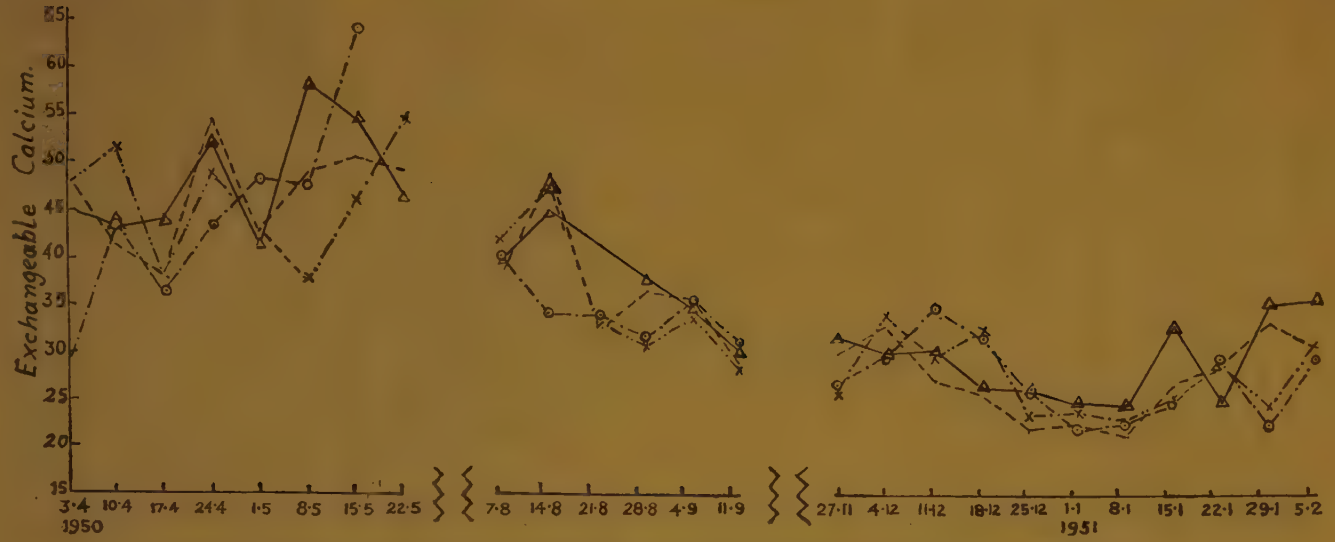


FIG. 8. Seasonal variations in exchangeable calcium of the soil in the four types of vegetation.

3. The soil R.H. is much higher in the open grassy area (Nursery Block), as compared to the other three blocks for the same temperature, say at 16° C.

4. The decrease in soil R.H. is more marked in the open grassy area with the rise of temperature, say upto 25° C., while it is the least in the sal plantation (Canal Block). It may be stated that teak at this time of the year was leafless.

5. At higher temperature, say at 40° C., the soil R.H. is at equal levels at 0″ depth in all the four pits.

6. 48″ depth shows higher soil R.H. as compared to the other depths at the same temperatures in all the blocks. This may show that atmospheric temperature and rainfall do not make much effect in the soil below the depth of 48″. The relationship shown in these figures indicates the effect on soil climate of different types of vegetation on the same type of soil during the same period.

In addition to the relationship discussed above soil temperature seems to govern the amount of exchangeable calcium in the soil profiles, as will be shown below. During the summer, when the soil temperature and also atmospheric temperatures show a rise the amount of exchangeable calcium in the soil seems to be high. It becomes low with low temperatures during the winter months. During the rainy monsoon period although a similar relationship is indicated it is not very clear due to the effect of leaching by rain water.

The soil temperatures, on the whole, related to atmospheric temperatures but the bracing effect of vegetation is clearly seen in sal and teak plantations. During summer, when temperature was high in the open, low figures were recorded under teak and sal. During the winter period higher temperatures were found in sal as compared to chir pine and open areas. The low figures in teak in winter were due to its being leafless. In all the pits there was a great difference in surface and subsoil temperatures, these differences were, however, smaller during rains. Under teak, subsoil temperatures were generally lower than in the other three areas.

Exchangeable Calcium of the Soil

Calcium is one of those soil minerals that are easily leached from the colloidal complex. In humid climates where P/E is high, the upper layers of the soil are very greatly leached and accumulation of calcium in the subsoil takes place.

In dry regions with pronounced evaporation, the surface layers become rich in bases and in intermediate climates the soil development with respect to the movement of the soil calcium is not completed and there occur azonal or immature soils. In the Dehra Dun valley the soils are mostly azonal. Due to the monsoonic pattern of rainfall in the area, the period of leaching from the surface is interrupted by the period of evaporation as a result of which downward or upward movement of Ca is not completed one way or the other.

Graph No. 9. Showing relation between Exchangeable Calcium and Depths

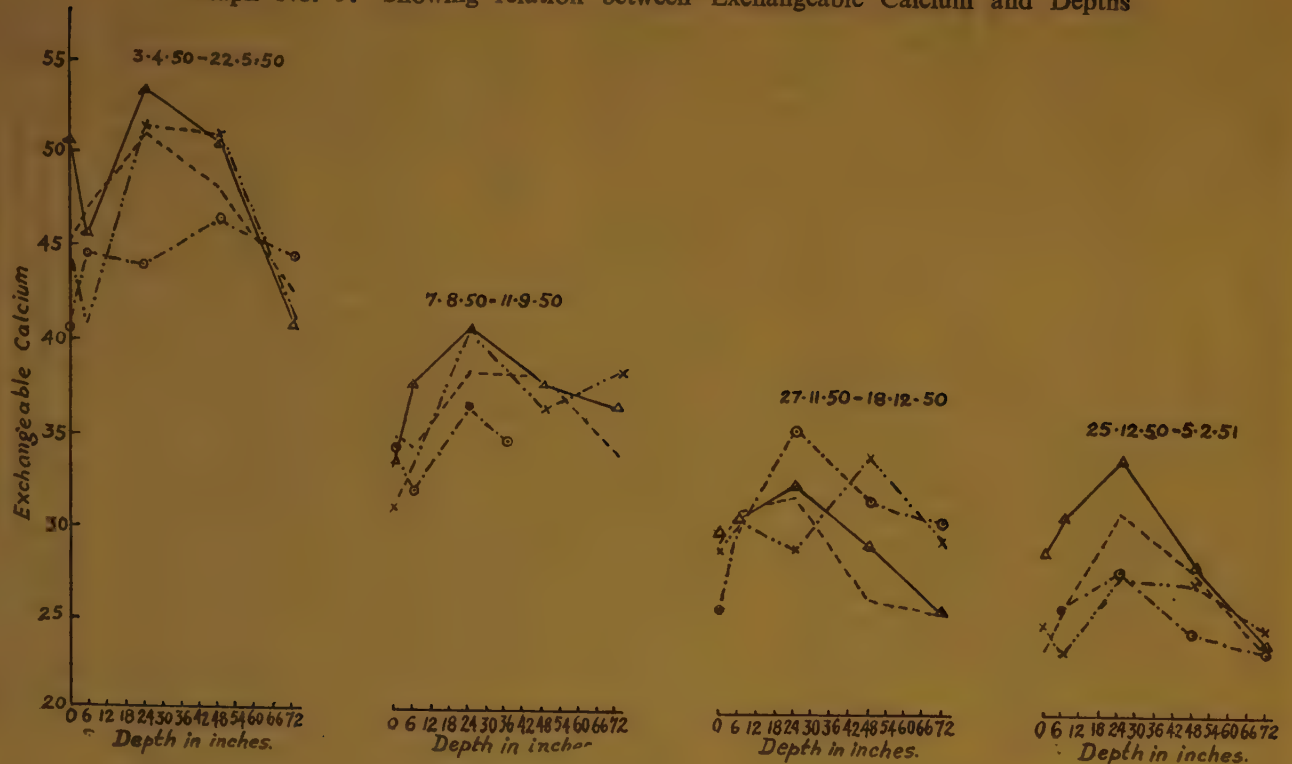


FIG. 9. Relationship of exchangeable calcium with depths in the soil profile under the four vegetation types.

The characteristic feature of soil profile of such a region is that the Ca-rich layer is not found at a constant depth from the surface.

In addition to rainfall, the vegetation cover, and the composition of tree litter also influence the translocation of Ca in the soil profile.

In the present investigation the parent material of the soil is more or less uniform, so differences in the soil Ca are ascribable to different physical and physiological characteristics of the tree vegetation.

Variations in the soil calcium in the four areas with respect to season and depth are shown in Figs. 8 and 9.

On the whole, exchangeable calcium in the entire profile during summer is high and it shows a decrease from dry to humid periods (Fig. 8). During the dry summer, from 3–4–1950 to 25–5–1950, exchangeable calcium shows a more or less rhythmical increase in all the cases. In the teak and sal plantations it decreases from 0″ to 6″ and then increases at 24″ and shows a decrease at lower depths. In the chir pine and open grassy areas, on the other hand, there is an increase from 0″ to 6″, and then in the chir pine the curve is of the same type as in teak and sal. But there follows a rhythmic change in the open grassy area.

In the rainy period, exchangeable calcium of the soil decreases in stages from 7–8–1950 to 11–9–1950 in all the cases. As seen in Fig. 9, there is an increase in exchangeable calcium from 0″ to 24″ under teak and sal, but in the chir pine and open areas there is a decrease from 0″ to 6″, followed by an increase at 24″ and below that the trend of variation becomes different in sal and teak, but is more or less similar in the period between 27–11–1950 to 18–12–1950.

In the period from 25–12–1950 to 5–2–1951, similar trend is seen in teak chir pine and in the open areas. Sal again shows a slight difference from this trend.

It is interesting to see that exchangeable calcium of the soil is high in the dry summer and low in cold humid period. This may be due to leaching of calcium in the humid period, or due to greater absorption of this mineral from the soil by the growing vegetation.

In another series of studies conducted by Puri and Gupta (1952) during the same period on seasonal variation in the foliar calcium of forest tree species occurring in the area it was seen that calcium content in leaves of all the tree species investigated was low in the early stages of their growth, which coincides with dry summer period; and calcium content was high at, or near the leaf-fall stage, which coincides with the humid winter period. Thus, it may seem that in the humid winter period, calcium is lost from the soil not only by leaching but also by absorption of the vegetation growing in the area.

In these investigations it has not been possible to consider the ground vegetation but it seems likely that these species may be taking greater amount of soil calcium than the trees. The competition between tree seedlings and ground flora species in this respect is worth investigating, as it is generally believed that a certain type of ground flora

species compete and suppress sal seedlings in some types of forests. The competition may be for moisture and minerals and not merely physical.

Summary

Studies on "soil climate" in the four plantations in the Demonstration Area of the New Forest have been made for the dry summer, monsoon rain, dry winter and rainy winter periods.

A large amount of variation in different elements of soil climate were found during different seasons and at various depths in the soil. There is an indication of the existence of a relationship of pH, Ca content, temperature and soil relative humidity with tree cover but it is not possible at present to explain the real causes of this or the possible effects of variations in "soil climate" with vegetation.

Lowest pH values were found in the sal plantation and highest values were obtained in the teak. The other two areas had intermediate pH values. Interesting variations in soil calcium were also seen. The variations with depth of soil Ca seem to be related in addition to vegetal cover with rainfall and temperature differences. For example, during the rainy season surface soils had lower amounts and a Ca-high layer seemed to be formed at the depth of 24″ to 36″ in different plantations.

During the hot weather, the surface soils had higher Ca content but 6″ layer had lower amounts in most cases. On the whole, higher Ca contents were seen in all the plantations during the rainless dry period and the lowest values were obtained during rainy winter period. This may be due to the loss of Ca by leaching or by the absorption of this element by growing plants. The latter possibility seems to be true, for we found high amounts of Ca in leaves of some trees from these plantations in winter and low amounts in dry rainy weather.

Temperature and soil relative humidity also showed very interesting relationships with the vegetal cover and season. On the whole, lower temperatures were found in hot weather in the teak and sal and high temperatures were encountered during the winter period in sal. Soils in the open showed greater fluctuations in soil temperature and soil relative humidity than those under forest trees. This shows the bracing effects of vegetation on soil climate.

Although, the relationship of the soil climate with the growth and succession of ground vegetation, could not be studied. It seems likely that these changes do have a good deal of effect on growing vegetation.

It will be desirable to extend such studies to forest areas, especially in plots where natural regeneration of various tree species is reported to be unsuccessful so that practical techniques of obtaining successful regeneration of desired species could be evolved.

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THE EMBRYO-SAC OF *ACALYPHA CILIATA* FORSK.

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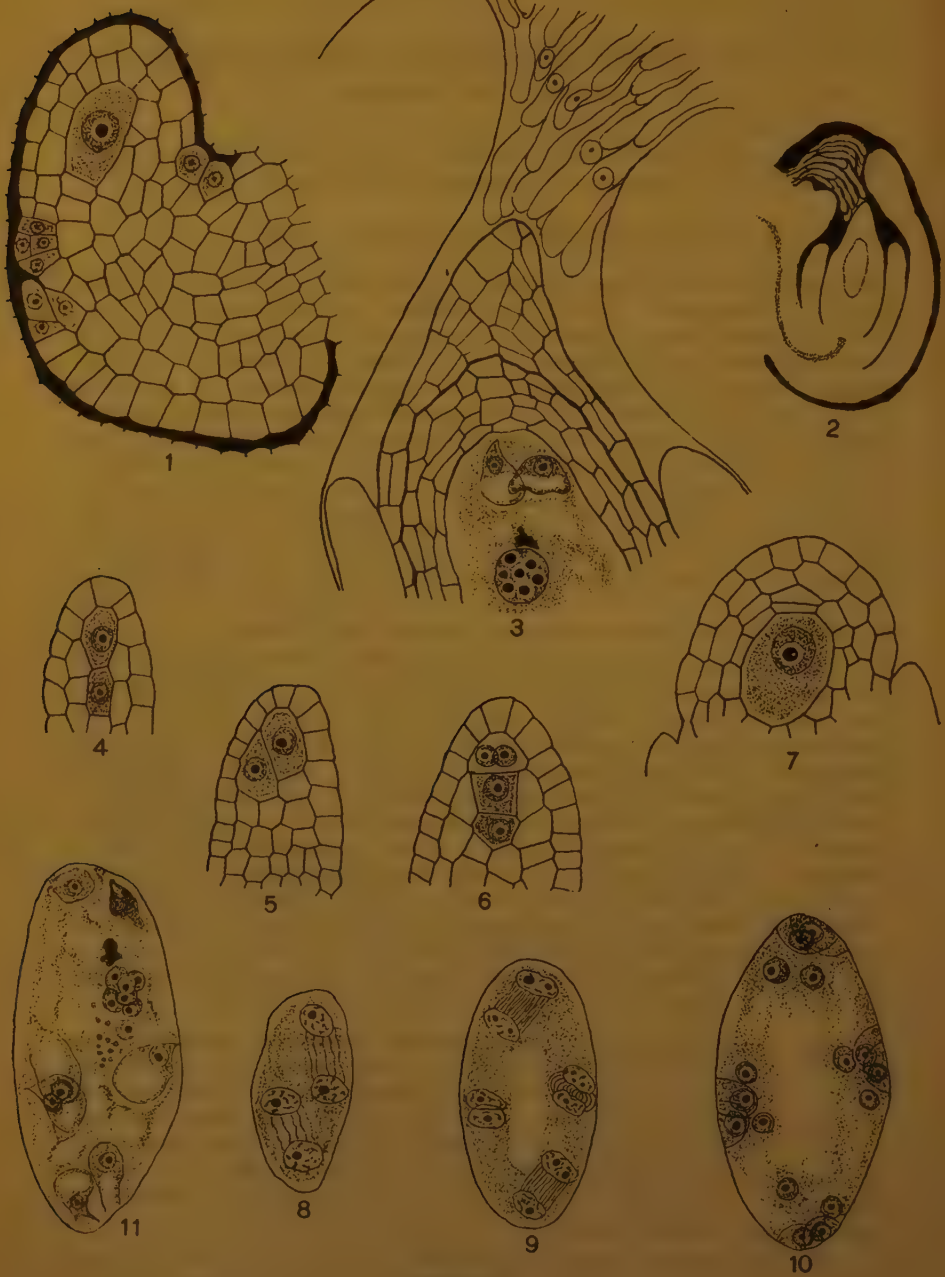
The genus *Acalypha* (Euphorbiaceæ) is well-known for the tetrasporic forms of embryo-sacs. So far three different types have been reported: (1) The *Penæa* type is known in *A. australis* (Tateishi, 1927), *A. tricolour* (Swamy and Balakrishna, 1946) and *A. rhomboidea* (Landes, 1946). According to Arnoldi (1912), another species of *Acalypha* also shows the same type. (2) The organization of the mature embryo-sac in *Acalypha lanceolata* conforms to the *Peperomia hispidula* form (Thathachar, 1952). (3) A different form of embryo-sac which is regarded as intermediate between *Plumbago* and *Penæa* types has been reported in *A. indica* by Maheshwari and Johri (1940 and 1941), who have termed it as the *Acalypha indica* type. A similar type of embryo-sac has been reported by Banerji (1949) in *A. fallax*. The present paper deals with the development of the ovule and embryo-sac of *Acalypha ciliata* Forsk., a species common near Poona.

Each loculus of the trilocular ovary contains one anatropous ovule hanging down from the axile placenta (Fig. 2). The ovules are bitegmic. The inner integument remains free from the nucellus and the outer one is free from the inner up to the mature embryo-sac stage. The micropyle which points upwards is formed by the outer integument only (Figs. 2 and 3). The initials of both the integuments appear almost simultaneously when the megaspore mother-cell is being differentiated (Fig. 1). The growth of the two integuments, however, is unequal. The outer integument grows faster than the inner and forms the micropyle at the mature embryo-sac stage, while the inner one covers about two-thirds of the nucellus at this time (Fig. 2). The integuments at this stage consist mostly of three to four layers of cells throughout their length except at the tip where the outer one is thicker and the inner is thinner.

The obturator arises as an outgrowth from the placenta above the funiculus. It consists of elongated vacuolated parenchymatous cells. The distal end of the obturator bends downward, projects into the micropyle and covers the apex of the nucellar beak (Figs. 2 and 3). The beak is organized both by the parietal tissue and the nucellar epidermis, the latter forming six to eight layers of cells directly below the micropyle but gradually decreasing to a single layer towards the chalazal ends of the nucellus (Fig. 3).

Usually there is a single hypodermal archesporial cell (Fig. 4), but sometimes two or three archesporial cells may be found (Fig. 5).



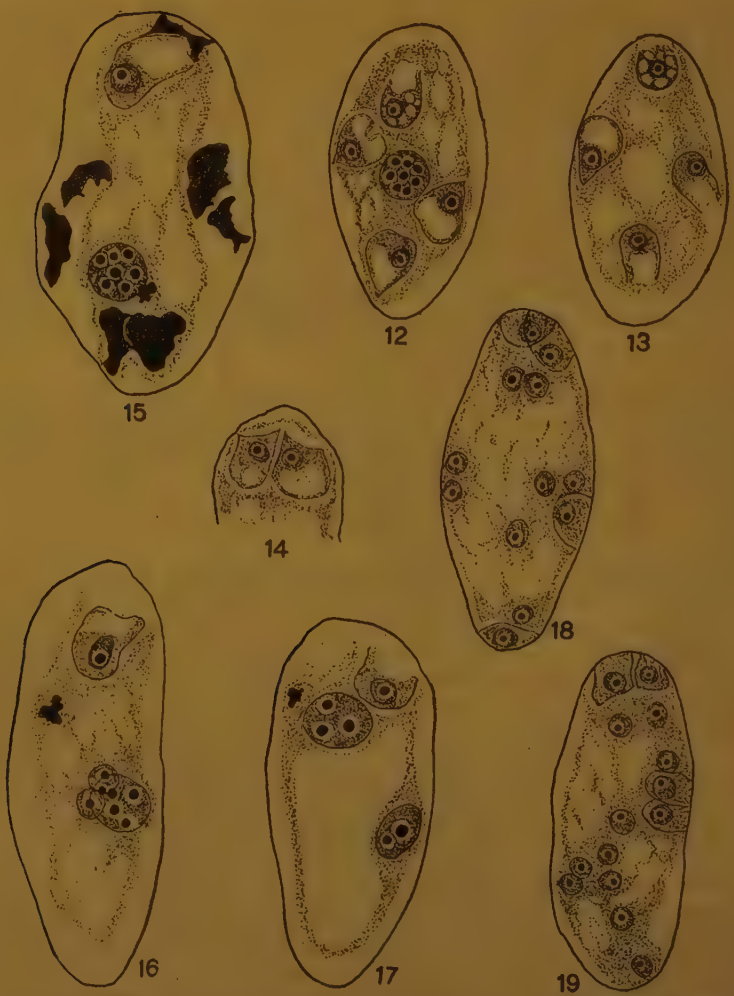
FIGS. 1–11

FIGS. 1–11. *Acalypha ciliata.* Fig. 1. L.S. of a young ovule showing megaspore mother-cell and initials of the integuments. Fig. 2. L.S. of a ovule at the mature embryo-sac stage. Note the obturator and the vascular strand. Fig. 3. L.S. of the apical part of the ovule showing cells of the obturator and the nucellar beak formed by the epidermis and the parietal tissue. Note the presence of two synergids (one on the right is cut half), a heptaploid secondary nucleus and a degenerating polar inside the embryo-sac. Fig. 4. L.S. of the nucellus showing archesporial cell mounted on a supporting cell. Fig. 5. The same showing two archesporial cells. Fig. 6. The same showing parietal cells, a megaspore mother-cell and a supporting cell. Fig. 7. The same showing enlarged megaspore mother-cell. Figs. 8 and 9. 4- and 8-nucleate embryo-sacs respectively. Fig. 10. A mature embryo-sac showing 8 free nuclei and 4 groups of egg apparatus. Fig. 11. A mature embryo-sac showing 3 egg apparatuses, 8 polars out of which one is degenerating, and starch grains. The egg in one of the lateral groups on the right hand side is not shown. Only the synergid is represented. The egg in the micropylar group is cut half and the synergid is degenerating. Fig. 2, ×225; the rest, ×700.

Such a variation in the number of archesporial cells is also reported in *A. lanceolata* (Thathachar, 1952), *A. indica* (Maheshwari and Johri 1940) and *A. tricolour* (Swamy and Balakrishna, 1946). The archesporium cuts off a primary parietal cell and a megaspore mother-cell (Fig. 6). The former divides further and forms four to six layers of parietal tissue at the mature embryo-sac stage (Fig. 3).

The megaspore mother-cell increases in size (Fig. 7). The nucleus undergoes two divisions and forms four nuclei. No walls are laid between these nuclei, which are arranged in a cross-wise fashion inside the embryo-sac, as in other species of *Acalypha* (Fig. 8). In this very position each one of them divides twice resulting in four distinct groups, each consisting of four nuclei. Thus the 16-nucleate condition is reached (Figs. 9 and 10). Two of the quartets occupy the two ends of the embryo-sac. The remaining two are at the sides commonly occupying the equatorial region of the embryo-sac opposite to each other (Figs. 10 and 15). A central vacuole becomes prominent by the time the embryo-sac is eight-nucleate (Fig. 9).

Two nuclei from each quartet organize into the egg apparatus consisting of an egg and a synergid. Ordinarily both these parts show a close resemblance to the egg and synergid of ordinary angiosperms in respect of shape, size, vacuolation and position of the nucleus (Figs. 11 to 13), but in some cases both the cells in a group had either an egg-like or synergid-like appearance (Figs. 12 to 14 and 3). The synergids are hooked (Figs. 11 and 14). The egg apparatus at the micropylar end points towards the micropyle. The one at the chalazal end is inverted, for it points towards the chalaza (Fig. 11). The two lateral groups are directed outwards, but are inclined in varying degrees either pointing towards the micropyle or the chalaza (Figs. 11 to 13). It is further observed that the two cells of a lateral group instead of being inclined towards one direction may be pointing in opposite directions (Figs. 12 and 13). In some embryo-sacs the two lateral groups were near the chalazal end (Fig. 11). Frequent occurrence of lateral egg apparatuses on either side of the antipodal group is also reported in *A. tricolour* by Swamy and Balakrishna (1946).



FIGS. 12–19. *Acalypha ciliata*. Figs. 12 and 13. Two figures of the same embryo-sac showing octoploid secondary nucleus and 4 groups of the egg apparatus. Fig. 14. The micropylar part of an embryo-sac showing a pair of synergids. Fig. 15. An embryo-sac showing 3 degenerating egg apparatuses, a heptaploid secondary nucleus, and the functional egg with a part of the degenerating synergid near it. Note also the degenerating polar nucleus. Fig. 16. An embryo-sac showing egg, a degenerating polar and the formation of secondary nucleus. Fig. 17. The same as above with two distinct nuclei formed by the polars. Figs. 18 and 19. Abnormal embryo-sacs. For further explanation see text, ×700.

The egg situated at the micropylar end alone is functional. The remaining three groups along with the synergid at the micropylar end degenerate during further development (Fig. 15). Starch grains are present in the mature embryo-sac (Fig. 11).

The organization of the secondary nucleus is quite interesting. Out of the 16 nuclei, eight nuclei—two from each group—remain free. All these, however, do not fuse to form an octoploid secondary nucleus, but only seven of them do so while the eighth commonly degenerates (Figs. 11 and 15 to 17). Only occasionally all the eight-nuclei fuse to form an octoploid secondary nucleus (Fig. 12). The cause leading to the degeneration of one of the polars is not known. Nor is it possible to say definitely as to which of the four groups the degenerating nucleus belongs, but probably it comes from the micropylar group on account of its more frequent position on that side (Figs. 3, 11, 16 and 17).

The polar nuclei may fuse in groups, which by subsequent fusion form an heptaploid secondary nucleus, or all of them might fuse simultaneously to achieve the same result (Figs. 11, 15 and 16). In a few cases it was seen that the polars fused in two groups to form two distinct nuclei (Fig. 17).

The position of the secondary nucleus inside the embryo-sac is not fixed. It may be situated somewhere near the functional egg or in the middle or towards the chalazal end of the embryo-sac (Figs. 3, 11, 12, 15 and 16).

The organization of the mature embryo-sac showed the following variations. In one embryo-sac there were 12 nuclei (four cells and eight free nuclei) instead of the normal 16 (Fig. 18). In this embryo-sac the micropylar group had two cells and two free nuclei. The chalazal group showed one cell and one free nucleus. One of the lateral groups had one cell and three free nuclei while the other had only two free nuclei (Fig. 18). Another embryo-sac had 14 nuclei (10 free nuceli and four cells) as shown in Fig. 19. The micropylar and one of the lateral groups had two cells and two free nuclei each. The other lateral group had four free nuclei, while in the chalazal one there were two free nuclei. Such embryo-sacs having less nuclei than the normal compliment of 16 have obviously resulted from the omission of some nuclear divisions.

Summary and Conclusion

The development and the structure of the ovule and embryo-sac in *Acalypha ciliata* are described. The outer integument forms the micropyle. The obturator covers the apex of the nucellar beak formed by the parietal tissue and the nucellar epidermis.

The archesporium is hypodermal. It consists generally of one but sometimes of two or three cells. The embryo-sac is tetrasporic and conforms to the *Acalypha indica* type, but differs in having heptaploid secondary nucleus, because one of the polars degenerates during development.

Acknowledgments

Our sincere thanks are due to Prof. S. P. Agharkar for his kind interest and to Dr. A. C. Joshi for his helpful criticism and advice.

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EMBRYOLOGICAL STUDIES IN THE LEGUMINOSÆ

IX. Development of the Endosperm and Embryo in *Dichrostachys cinerea* W. & A. and *Parkia biglandulosa* W. & A.

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In a previous paper (Dnyansagar, 1954 *a*), the author described the inflorescence, sporogenesis and gametophytes of *Dichrostachys cinerea* W. & A. and *Parkia biglandulosa* W. & A. The present paper deals with the development of the endosperm and embryo in these plants.

Material and Methods

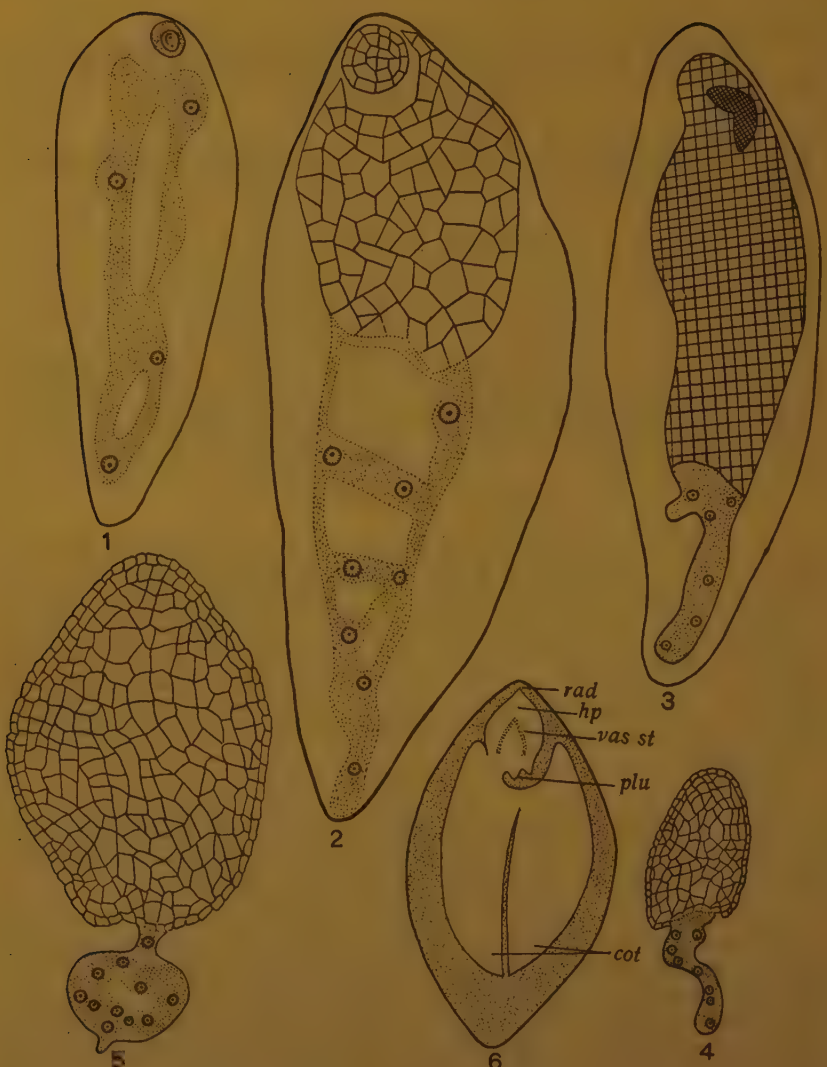
The material of *Dichrostachys cinerea* was supplied by Prof. P. Maheshwari from Delhi, Dr. B. M. Johri from Bharatpur and Prof. T. S. Sadasivan from Madras and that of *Parkia biglandulosa* by Dr. K. Subramanyam and Shri Anantaswamy Rau from Bangalore. It was fixed in formalin-acetic-alcohol and Randolph's modification of Navaschin's fluid. The sections were cut 10–15 μ thick and stained with iron-alum hæmatoxylin, Harris' hæmatoxylin and Ehrlich's hæmatoxylin. The dissected endosperms were stained by Zirkle's acetocarmine.

Endosperm

The endosperm develops according to the Nuclear type. This is a characteristic feature of the Leguminosæ since the same type has been observed in all the investigated species of the order.

After the completion of double fertilization, which follows the normal course, the primary endosperm nucleus starts dividing immediately, while the oospore undergoes a period of rest (Figs. 1, 7). By the time the latter undergoes the first division, several endosperm nuclei are already formed (Fig. 8). These nuclei become distributed along the periphery of the embryo-sac, which enlarges considerably, growing particularly in length at the cost of the nucellar tissue. The nuclei are at first equally distributed, but soon they gather at the micropylar and chalazal ends to form prominent accumulations.

Cell-formation in the endosperm commences from the micropylar end after the embryo has become several-celled (Figs. 2, 9) and gradually spreads towards the chalaza. The endosperm at the chalazal end, however, remains free nuclear for a very long time. It is so even as late as the appearance of cotyledons in the embryo (Fig. 3). This part of the endosperm has at first the shape of a narrow tube (Fig. 4),

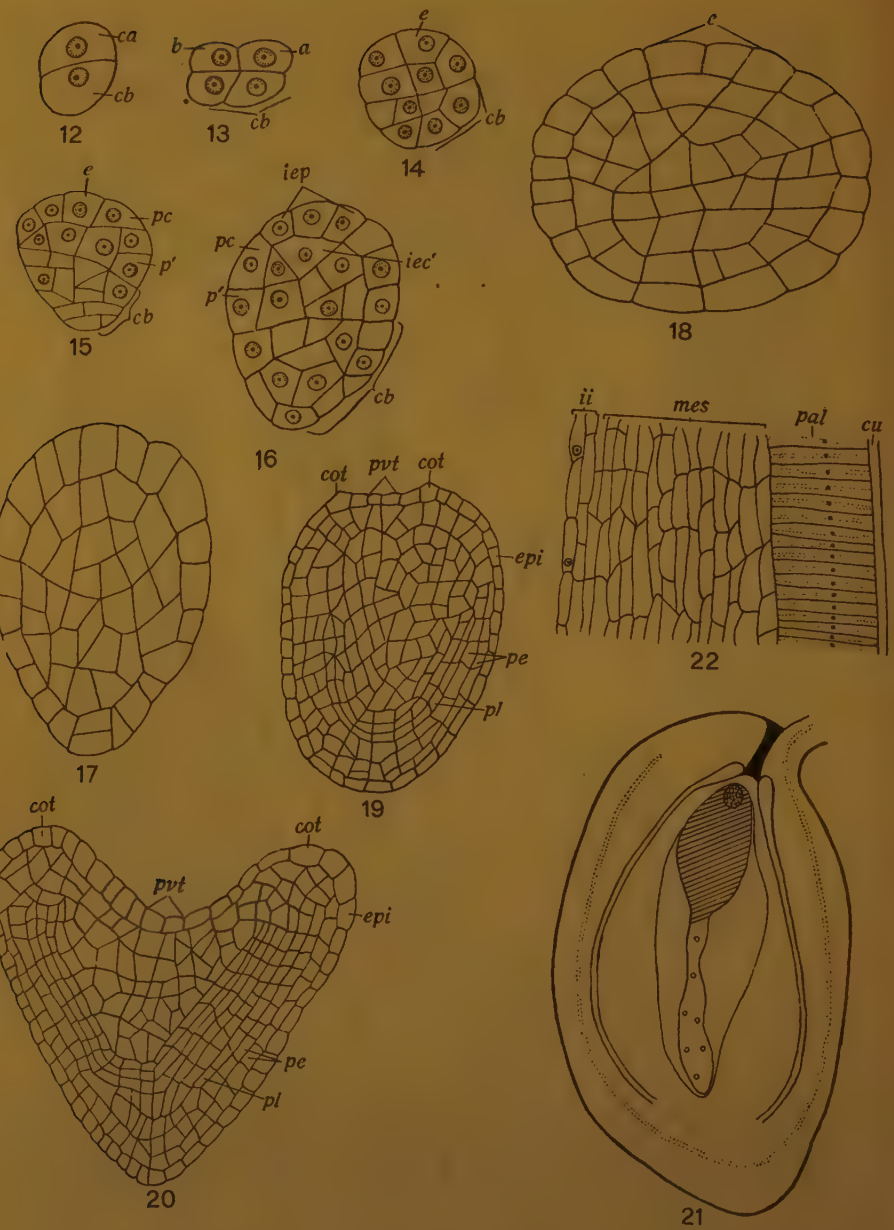


FIGS. 1–6. *Dichrostachys cinerea*. Fig. 1. Embryo-sac showing oospore and four endosperm nuclei, ×275. Fig. 2. The same showing spherical massive proembryo, formation of cellular endosperm in micropylar region and free endosperm nuclei below, ×275. Fig. 3. The cellular endosperm advancing towards the micropyle and free nuclei in chalazal region at the stage when cotyledons have appeared in the embryo, ×25. Figs. 4 and 5. Entire endosperms dissected out from growing seeds showing cellular micropylar part and chalazal haustorium (embryo not shown), ×55. Fig. 6. Cellular endosperm surrounding embryo at advanced stage. *cot*, cotyledons; *hp*, hypocotyl; *plu*, plumule; *rad*, radicle and *vas st*, vascular strand, ×12·5.

but as the process of cell-formation extends towards the chalaza, it assumes a bulbous form with a pointed apex in *Dichrostachys cinerea* (Fig. 5). This free nuclear process (Figs. 4, 5, 10, 11) in both the plants plays a haustorial role, absorbing nourishment from the chalazal tissue with which it comes into deep contact. The persistence of a free nuclear endosperm in the chalazal part for a long time and its coming into intimate contact with the nucellus by extending into it or by forming a haustorial process, has been observed in several plants belonging to the Leguminosæ, *viz.*, *Melilotus alba* (Young, 1905), *Crotalaria* (Rau, 1951 *a*), *Glycine javanica*, *Tephrosia purpurea*, *Tephrosia procumbens*, *Clitoria ternatea* and *Pongamia glabra* (Rau, 1951 *c*), *Heylandia*

FIGS. 7–11. *Parkia biglandulosa*. Fig. 7. Embryo-sac showing oospore and endosperm nuclei, ×275. Fig. 8. Micropylar part of embryo-sac showing 2-celled proembryo and endosperm nuclei, ×275. Fig. 9. Embryo-sac showing spherical massive proembryo, formation of cellular endosperm in micropylar region and free endosperm nuclei below, ×75. Figs. 10 and 11. Dissected endosperm showing cellular micropylar part and chalazal haustorium (embryo not shown), ×162·5.

latebrosa, *Cyamopsis psoraloides*, *Eleiotis sororia*, *Desmodium*, *Teramus labiales*, *Atylosia scaraboides* and *Abrus precatorius* (Rau, 1953) of the Papilionaceæ, *Cassia tora* (Rau, 1950), *Cassia occidentalis*, *Cassia auriculata* and *Cassia glauca* (Pantulu, 1951) of the Cæsalpiniaceæ, *Prosopis spicigera* (Dnyansagar, 1953), *Neptunia triquetra* (Dnyansagar, 1954 *b*),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FIGS. 12–22

FIGS. 12–22. *Dichrostachys cinerea*. Figs. 12–20. Various stages showing development of embryo. Description in text. *cot*, cotyledon; *epi*, epidermis; *pe*, periblem and *pl*, plerome. Fig. 21. L.S. of developing seed showing post-chalazal extension of vascular strand. Fig. 22. L.S. of part of seed-coat. *cu*, cuticle; *ii*, inner integument; *mes*, mesophyll and *pal*, palisade. Figs. 12–18, ×600; Figs. 19, 20, ×275; Fig. 21, ×60; Fig. 22, ×275.

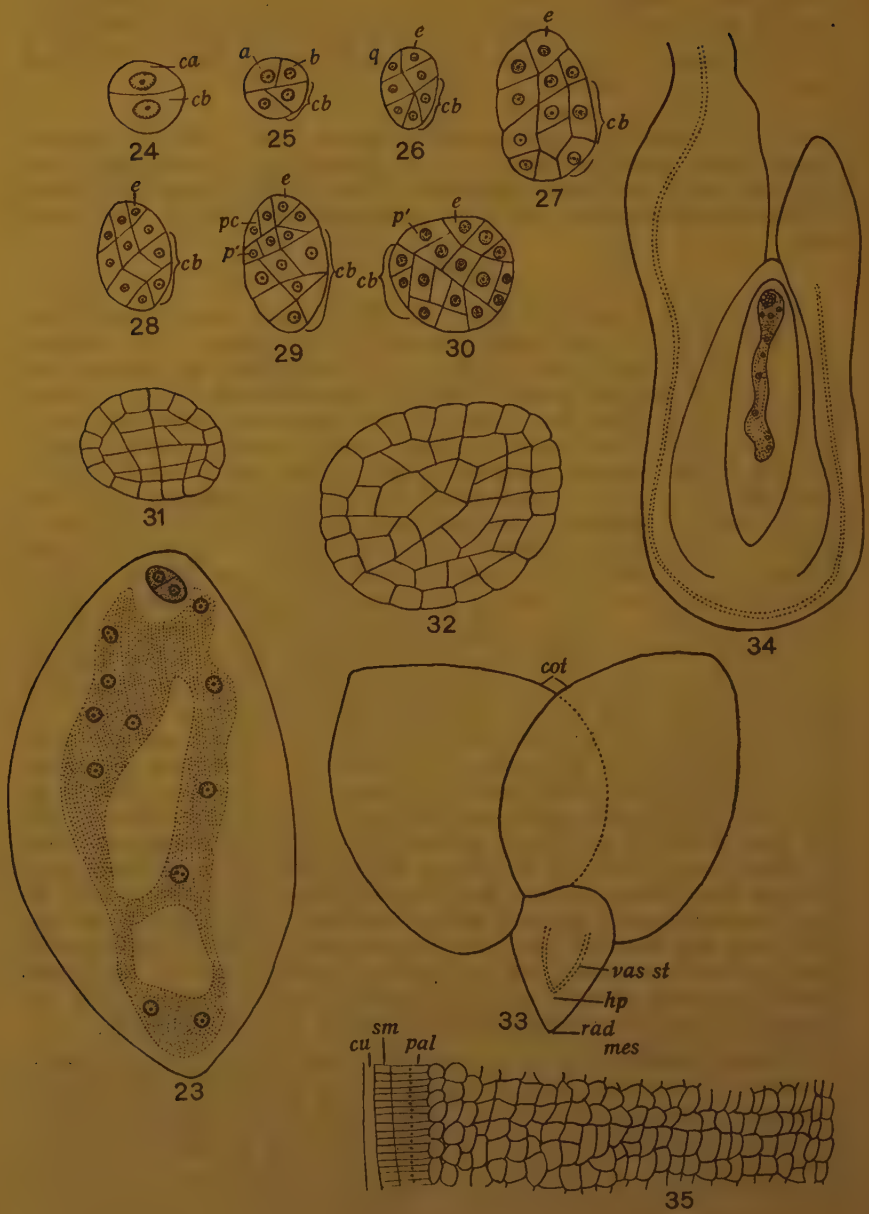
Acacia auriculæformis, *Adenanthera pavonina* and *Calliandra haematocephala* (Dnyansagar, 1954 *c*) of the Mimosaceæ. Ultimately, however, the entire endosperm becomes cellular (Fig. 6) and is absorbed by the growing embryo. No trace of endosperm is left in the mature seed.

EMBRYO

Dichrostachys cinerea (Figs. 6, 12–20).—The oospore divides transversely to form the two-celled proembryo consisting of the terminal cell, *ca* and the basal cell, *cb* (Fig. 12). These cells by oblique divisions form a globular tetrad (Fig. 13) corresponding to the category B_1 of the Series B of the system of the embryogenic classification of Souèges (1941). The two cells of the tetrad derived from *ca* namely *a* and *b* are juxtaposed. *a* occupies the summit and is larger than *b*. These cells give rise to quadrants. One of the quadrants which lies at the summit functions as the epiphysis initial, *e* (Fig. 14). Figures 15 and 16 show further divisions in the quadrants. These are mostly oblique or tangential and it becomes difficult to follow with certainty any regular sequence and recognise actual limits of the cellular layers formed by cells, *ca* and *cb*. At the fourth cell-generation, however, first initials of the epidermis are differentiated towards the outside. The division in the epiphysis initial, *e* is also at first tangential. The resulting upper cell divides vertically and thus isolates elements of dermatogen, *iep* of the stem apex, *pvt* (Fig. 16). The lower cell gives rise to the initials of the cortex, *iec'* of the *pvt*. The three quadrants below the epiphysis initial become arranged into two tiers, *pc* and *p'*. As a result of irregular divisions after the fourth cell-generation, a massive pear-shaped (Fig. 17) or globular (Fig. 18) proembryo indicating the direction of the axis is formed where there is no differentiation between the embryo proper and the suspensor. Figures 19 and 20 show more advanced stages of the embryo where the lobing of the two cotyledons has been initiated and the epidermis, periblem and plerome have been differentiated. Of the mature embryo (Fig. 6), the downwardly pointing radicle, broad hypo-cotyledonary region and the prominent cotyledons enclosing the plumule are characteristic.

Parkia biglandulosa (Figs. 24–33).—The mode of development of the embryo in this plant is almost similar to that of *Dichrostachys cinerea*. The tetrad (Fig. 25) is of the same category, but it is difficult to determine the position of the quadrants, that is differentiation of the epiphysis and of the quadrants below the epiphysis and their subsequent arrangement in two tiers, *pc* and *p'*.

Occasionally in this plant, the egg is found to be attached laterally and hence the dividing wall does not appear to be transverse (Fig. 23). But in all cases, however, the developing proembryo soon appears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FIGS. 23–35

FIGS. 23–35. *Parkia biglandulosa*. Fig. 23. Embryo-sac showing 2-celled proembryo laterally attached and endosperm nuclei. FIGS. 24–32. Various stages showing development of embryo. Description in text. Legends same as for Figs. 12–20. Fig. 33. Dissected embryo showing cotyledons, *cot*; hypocotyl, *hp*; radicle, *rad*, and vascular strand, *vas st*. Fig. 34. L.S. of developing seed at the massive proembryo stage showing post-chalazal extension of vascular strand (inner integument has been consumed). Fig. 35. L.S. of part of seed-coat. *cu*, cuticle; *mes*, mesophyll; *pal*, palisade and *sm*, mucilage-stratum. Figs. 23–32, ×600; Fig. 33, ×25; Fig. 34, ×60; Fig. 35, ×325.

at the apex of the sac. A similar condition has been reported by Newman (1934) in *Acacia Baileyana*.

Formation of the massive type of the proembryo where there is no differentiation between the embryo proper and the suspensor has been observed among the Mimosaceæ in *Mimosa pudica* (Guignard, 1881; Narasimhachar, 1951), *M. denhartii* (Guignard, 1881), *M. hamata* (Dnyansagar, 1951 *a*), *Acacia Baileyana* (Newman, 1934), *A. farnesiana* (Narasimhachar, 1948), *A. auriculæformis* (Dnyansagar, 1954 *c*), *Leucæna glauca* (Dnyansagar, 1949), *Pithecolobium saman* (Dnyansagar, 1951 *b*), *Desmanthus virgatus* (Dnyansagar, 1953) *Prosopis spicigera* (Dnyansagar, 1953, 1954 *b*), *Neptunia triquetra* (Dnyansagar, 1954 *b*), *Adenanthera pavonina* and *Calliandra hematocephala* (Dnyansagar, 1954 *c*).

Johansen (1950) has classified the embryogeny of *Acacia Baileyana* under the Trifolium Variation, Onagrad Type except that a suspensor is not formed. Souèges has worked out the embryogeny of *Genista tinctoria* (1947 *a*), *Ulex europæus* (1947 *b*), *Sarothamnus scoparius* (1947 *c*), *Thermopsis fabacea* (1948), *Dorycnium rectum* (1949) and *Tetragonolobus siliquosus* (1950) all belonging to the Papilionaceæ where the embryo proper is derived from the terminal cell of the two-celled proembryo while the basal cell forms the suspensor. The general course of development in these plants follows closely that of *Trifolium minus* (Souèges, 1929) but here the differentiation between the embryo proper and the suspensor is less distinct. A similar condition has been reported in *Colutea arborescens* (Crété, 1951) and *Sesbania ægyptiaca* (Rau, 1951 *b*). Souèges and Crété (1952) have classified the embryogeny of these plants under the Megarchtype VI *b* of the Series B of the First period where the first tetrad is of B_1 type. From a comparison of the figures showing the development of the embryo in these plants, it seems that the embryogeny of *Dichrostachys cinerea* and *Parkia biglandulosa* makes the nearest approach to them. And it may be that the tiers, *pc* and *p'* give rise to cotyledonary and hypocotyledonary and root zones respectively and the massive tissue derived from the basal cell, *cb* does not contribute to the construction of the embryo proper as in the above plants.

VASCULAR STRAND AND SEED-COAT

A single vascular strand lies in the region of the chalaza prior to fertilization, but there occurs the post-chalazal extension of the strand in the outer integument when the embryo is developing. The strand reaches almost up to the micropyle (Figs. 21, 34). Such a post-chalazal extension of the vascular strand has been observed by the author in

all the species of the Mimosaceæ investigated by him (1952, 1953, 1954 *c*) and seems to be a characteristic feature of the family. According to Corner (1951), with the exception of some species of *Bauhinia*, the post-chalazal extension of the strand occurs in the seeds of the Cæsalpiniaceæ and the Mimosaceæ.

Brown pigments probably of tannin appear in the cells of the outer integument and in the chalazal region of the nucellus after fertilization.

On the testa of the mature seed, there is a fine hooplike line on each side which is called by Corner (1951) as pleurogram. Corner (1951) has described in detail the structure of the testa of the mature seed of the Mimosaceæ in plants like *Parkia javanica*, *Albizzia*, *Mimosa pudica* and *Adenanthera pavonina*. The observations on the present species agree with these.

Summary

1. The endosperm remains free nuclear in the chalazal region up to a very late stage of seed development and forms a haustorial process.

2. The general course of the development of the embryo makes the nearest approach to the Megarchtype VI *b* of the Series B of the First period of Souèges or *Trifolium* Variation of Onagrad Type of Johansen except that a suspensor is not formed.

3. There takes place the post-fertilization extension of the chalazal vascular strand in the outer integument up to the micropyle.

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The author is grateful to Prof. R. L. Nirula for guidance and suggestions, to Dr. Souèges for going through the manuscript with respect to the embryogeny and valuable comments, to Prof. P. Maheshwari for going through the manuscript and supply of the material of *Dichrostachys cinerea*, to Shri U. Mukerjee, Principal, College of Science, Raipur for facilities and to the Ministry of Education, Government of India and the Education Department, Madhya Pradesh for the research grants. Thanks are also due to Prof. T. S. Sadasivan and Dr. B. M. Johri, for supplying the material of *Dichrostachys cinerea* and to Dr. K. Subramanyam and Shri Anantaswamy Rau for supplying the material of *Parkia biglandulosa*.

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EMBRYOLOGICAL STUDIES IN THE LEGUMINOSÆ

X. Supplementary Observations on the Development of the Endosperm and Embryo in *Leucaena glauca* Benth. and *Mimosa hamata* Willd.

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(Received for publication on March 15, 1954)

The author recorded a few observations on the development of the endosperm and embryo in *Leucæna glauca* (1949) and *Mimosa hamata* (1951 *a*) of the Mimosaceæ in his first and second papers respectively under the above series. A detailed study of the development of the endosperm and embryo of the above plants has been made now.

Material and Methods

Material of *Leucæna glauca* was collected from the Maharajbagh Gardens, Nagpur and that of *Mimosa hamata* from the Highland Drive Area, Nagpur. It was fixed in formalin-acetic-alcohol and Randolph's modification of Navaschin's fluid. Sections were cut 10–15 μ in thickness and were stained with iron-alum hæmatoxylin, Harris' hæmatoxylin and Ehrlich's hæmatoxylin. For whole mounts of the endosperm, Zirkle's acetocarmine was used.

Endosperm

The endosperm develops according to the Nuclear type as in all the investigated species of the Leguminosæ.

The primary endosperm nucleus divides before the fertilised egg, (Fig. 1) which rests for a while. When the oospore divides for the first time, some endosperm nuclei are already formed. These nuclei at first arrange themselves along the periphery of the sac and a central vacuole is formed (Fig. 2). By this time, the sac increases in size at the cost of the nucellar tissue. The endosperm nuclei then move and aggregate themselves particularly in micropylar and chalazal regions of the sac where the cytoplasm is dense. Vacuoles appear here and there.

Wall-formation takes place at first in the micropylar region around the embryo after the four-celled stage and then it gradually extends towards the chalazal region (Figs. 3 and 4). It is interesting to note that the chalazal part of the endosperm remains free nuclear even when the embryo has differentiated into cotyledons, radicle and plumule in *Leucæna glauca*. This chalazal free nuclear part of the endosperm in

FIGS. 1-10

FIGS. 1–10. *Leucæna glauca*. Fig. 1. Embryo-sac showing oospore and two endosperm nuclei. Fig. 2. Same, showing 4-celled proembryo and 6 endosperm nuclei arranged at periphery. Flg. 3. Same, showing a spherical massive proembryo, cellular endosperm in micropylar region and free endosperm nuclei below. Fig. 4. Endosperm showing micropylar cellular part surrounding proembryo and chalazal haustorium with free nuclei. Figs. 5–8. Whole mounts of endosperm at various stages. Fig. 9. L.S. of developing seed. *bt*, barrier tissue; *es*, embryo-sac; *tp*, tubular process of chalazal part of endosperm; *vas st*, vascular strand. FIG. 10. Barrier tissue below antipodal end of embryo-sac. FIGS. 1, 2, ×225; Figs. 3, 4, 9, 10, ×55; Figs. 5, 6, 8, ×50; Fig. 7, ×25.

Leucæna glauca is at first in the form of a long narrow tubular process tapering below (Figs. 5 and 6). In the whole mounts of the endosperm (Figs. 5–8), it is seen that this process is twisted. This may be due to increase in the mass of the endosperm tissue. As the process of the wall-formation extends more and more towards the chalazal end, the narrow tubular process becomes bulbous at its lower end (Fig. 8).

In *Mimosa hamata*, the chalazal part of the embryo-sac develops into a narrow tube also with free nuclei. It becomes enlarged at the end. This part shows a downwardly pointed projection in the centre (Figs. 11 *a*, *b*) and in its basal peripheral portion, cytoplasm is very dense (Fig. 11 *b*).

Formation of a tubular process with free nuclei in the chalazal part of the endosperm with a vesicular tip has been reported by Rau in *Crotalaria* (1951 *a*, 1953), *Heylandia latebrosa, Cyamopsis psoraloides, Eleiotis sororia* and *Desmodium* (1953) of the Papilionaceæ and by the author in *Dichrostachys cinerea* (1954 *c*) of the Mimosaceæ.

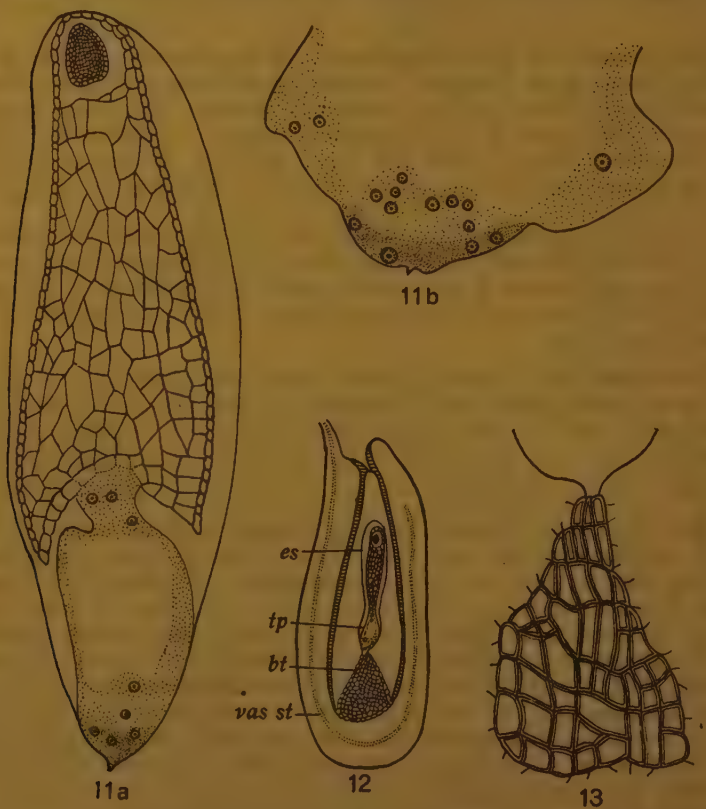
The vesicular tip comes in deep contact with the chalazal tissue of the nucellus and acts as a haustorium. But in later stages, further encroachment by this part of the endosperm is prevented by a barrier tissue (Figs. 9, 10, 12 and 13). The latter is formed by some of the cells of the nucellus between the antipodal end of the sac and the vascular strand becoming thick-walled and filled with brown pigments, probably tannin. Dahlgren (1940) has described formation of a barrier tissue for stopping the encroachment of the embryo-sac in several plants belonging to diverse families. He calls this tissue as "postament". He has not listed any species of the Leguminosæ in which it is formed. Recently, Rau has reported it in *Glycine*, *Clitoria ternatea*, *Tephrosia*, *Pongamia glabra* (1951 *c*), *Dalbergia sissoo*, *Indigofera* and *Teramus*, *labiales* (1953) of the Papilionaceæ and the author (1954 *a*) in *Neptunia triquetra* and *Prosopis spicigera* of the Mimosaceæ.

The formation of the free nuclear haustorium in the chalazal region by the endosperm has been observed in several plants of the Leguminosæ and the relevant literature has been reviewed by the author elsewhere (Dnyansagar, 1954 *a*, *b* and *c*).

In course of time, the whole of the endosperm becomes cellular and fills the entire cavity of the seed (Fig. 38). Then in its turn, the endosperm is resorbed completely by the developing embryo as the seed matures.

EMBRYO

Leucæna glauca (Figs. 14–25).—The first division of the oospore is transverse (Fig. 14). The products of this division, *viz.*, the terminal cell *ca* and the basal cell *cb* by further divisions give rise to a globular tetrad (Fig. 15). These divisions are not certainly absolutely vertical and yet it cannot be said that they are typically oblique. These from their nature serve to connect the strictly vertical divisions and the



FIGS. 11–13. *Mimosa hamata*—Fig. 11 *a*. Embryo-sac showing massive pro-embryo, cellular part of endosperm in micropylar region and tubular haustorium in chalazal region. Fig. 11 *b*. Terminal broad part of tubular process of chalazal endosperm with pointed projection. Fig. 12. L.S. of developing seed. Legends same as for Fig. 9. Fig. 13. Barrier tissue below antipodal end of embryo-sac. Figs. 11 *a*, *b*, 12, ×55; Fig. 13, ×225.

typically oblique divisions. The globular tetrad thus formed occupies in consequence an intermediate position between the A_1 of the Series A and B_1 of the Series B of Souèges' embryogenic system. The two daughter cells, *a* and *b* of *ca* divide to give rise to quadrants which are disposed in two superposed pairs (Fig. 16). The upper daughter cell of *a* which lies at the summit functions as the epiphysis initial *e*. At

the fourth cell-generation, the quadrants below the epiphysis (Fig. 17) become arranged in two tiers, *pc* and *p'*.

The elements of the upper tier, *pc*, adjacent to the epiphysis *e*, divide mostly obliquely and tangentially and ultimately produce the cotyledonary part *sensu stricto*, *pco* (Figs. 19 and 20). The cells of the lower tier, *p'*, by tangential and mostly oblique divisions give rise to the hypocotyledonary and root zones. It is after the fourth cell-generation that there is an indication that the cells of this tier, *p'*, start dividing transversely to form two tiers, *ph* and *h* forming the hypocotyledonary part and hypophysis respectively (Figs. 19 and 20). As further divisions are mostly oblique, it becomes difficult to make out any regular sequence.

The epiphysis initial, *e* divides at first by a longitudinal wall forming an upper and a lower cell. The upper cell divides by a vertical wall and thus isolates the initials of the epidermis, *iep*, of the stem apex, *pvt* (Figs. 18–20). The lower cell gives rise to the initials, *iec'* of the cortex of the stem apex.

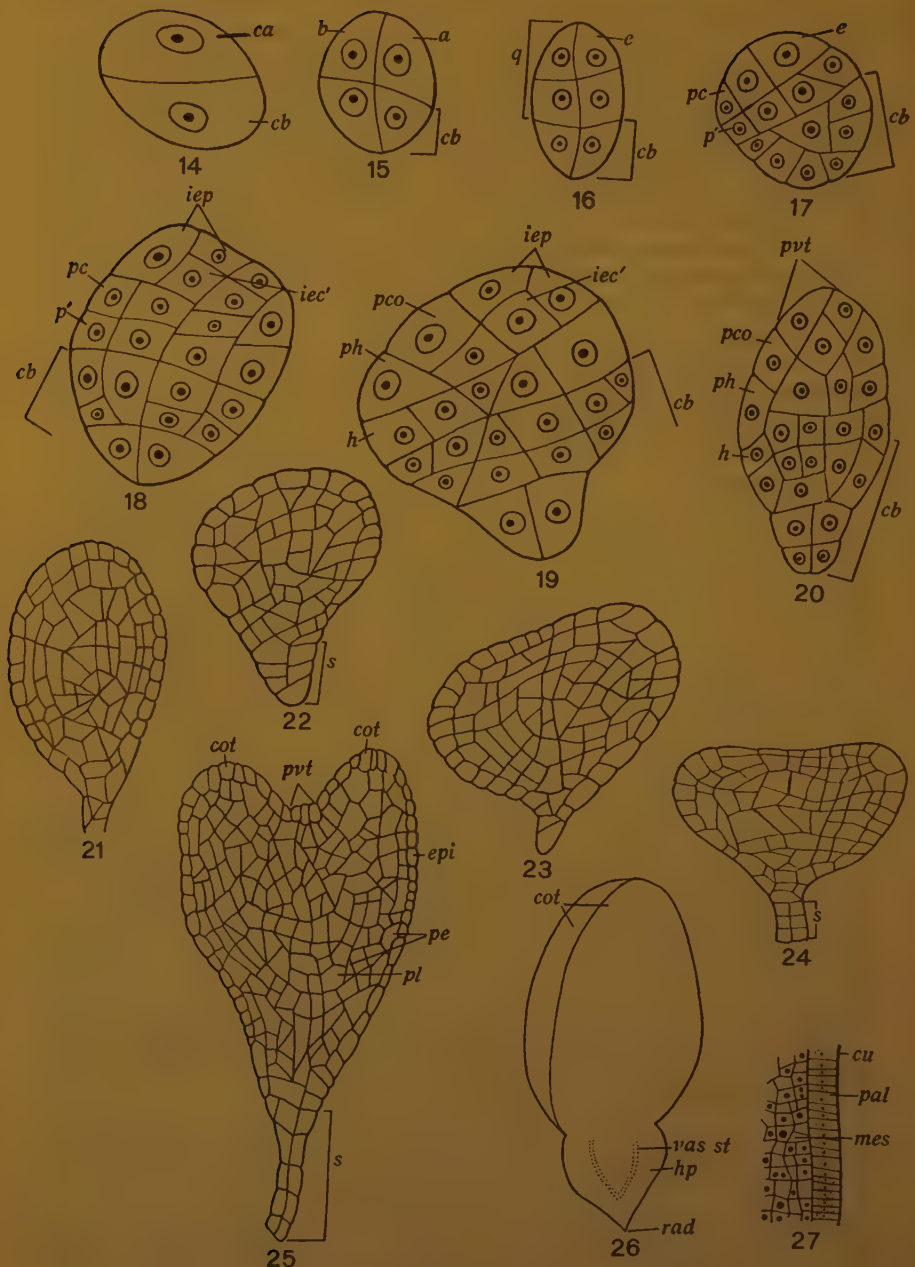
The basal cell, *cb* does not take part in the formation of the embryo proper. By a series of tangential and oblique divisions, it forms a massive structure. At this stage, the pro-embryo has a spherical shape and there is no apparent line of demarcation between the embryo proper and the tissue formed by the basal cell. It is interesting to note that the two terminal cells of this tissue remain very prominent. In later stages, these cells elongate somewhat and the proembryo becomes pear-shaped (Fig. 19). They undergo further divisions and form a filament of 6–12 cells (Figs. 22, 24 and 25). Thus the suspensor in the proembryo becomes quite prominent.

Periblem and plerome are differentiated when the cotyledons appear (Fig. 25). The root cap is organised in due course.

Mimosa hamata.—Various stages in the development of embryo in this plant are represented in Figs. 28–40. The embryonic development is almost similar to that in *Leucæna glauca* excepting that the divisions following the first cell-generation are typically oblique so that the globular tetrad is of B_1 type of the series B of Souèges' embryogenic system and the basal cells of the tissue derived from the basal cell, *cb* neither become prominent nor form filamentous part of the suspensor. The derivatives of the cell *cb* give rise to a massive tissue and do not contribute to the embryo proper. The proembryo remains massive and spherical or pear-shaped (Figs. 34–37). There is no apparent distinction between the suspensor and the embryo.

The mature embryo is symmetrical, possesses downwardly pointed thick and short radicle, broad hypocotyledonary region and prominent cotyledons which enclose the plumule (Figs. 26 and 40).

Johansen (1950) has recognised ,two types of embryogeny in the Mimosaceæ, one with and the other lacking a suspensor. They follow the Onagrad Type, Trifolium Variation. He has included *Cercis siliquastrum* under the first type. Guignard (1881) described the embryogeny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FIGS. 14–27

FIGS. 14–27. *Leucæna glauca*—Figs. 14–25. Various stages showing development of embryo. *cot*, cotyledon; *pe*, periblem; *pl*, plerome; *q*, quadrants. For explanation see Text-Fig. 26. Mature embryo. *cot*, cotyledons; *hp*, hypocotyl; *rad*, radicle; *vas st*, vascular strand. Fig. 27. L.S. part of seed-coat. *cu*, cuticle; *mes*, mesophyll; *pal*, palisade. Fig. 14, ×650; Figs. 15–19, ×500; Figs. 20–25, ×225; Fig. 26, ×25; Fig. 27, ×225.

of this plant under the Cæsalpiniaceæ. Engler and Gilg (1924) also consider it under the Cæsalpiniaceæ. Hence it appears that the position of *Cercis siliquastrum* in the Mimosaceæ is doubtful. Leaving aside, therefore, the case of this plant, it will be seen from the review of the related literature that a massive proembryo without differentiation between the embryo proper and the suspensor has been uniformly reported in the Mimosaceæ. Hence *Leucæna glauca* becomes the first authentic species of the Mimosaceæ where the presence of the suspensor is obvious at least in later stages of the proembryo.

From the above account, it is clear that the present plants follow the embryonomic type of *Trifolium minus* (Souèges, 1948 *b*) of the Papilionaceæ except that there is no apparent distinction between the suspensor and the embryo proper (in *Leucæna glauca* only in early stages). Souèges has reported *Genista tinctoria* (1947 *a*), *Ulex europæus* (1947 *b*), *Sarothamnus scoparius* (1947 *c*), *Thermopsis fabacea* (1948 *a*), *Dorycnium rectum* (1949) and *Tetragonolobus siliquosus* (1950) of the Papilionaceæ as showing the development of the embryo followed in *Trifolium minus* in broad outlines except that differentiation between the embryo proper and the suspensor is less distinct. Similar is the case in *Colutea arborescens* (Crété, 1951 *a*), *Astragalus Glycyphyllos* (Crété, 1951 *b*) and *Sesbania ægyptiaca* (Rau, 1951 *b*) of the Papilionaceæ.

In the light of the above considerations, it can be concluded that (1) among the Mimosaceæ *Leucæna glauca* serves to link the type of embryogeny shown by the above plants of the Papilionaceæ and the rest of the plants of the Mimosaceæ, *viz.*, *Acacia*, *Mimosa Denhartii* (Guignard, 1881), *Acacia Baileyana* (Newman, 1934), *Acacia farnesiana* (Narasimhachar, 1948), *Pithecolobium saman* (Dnyansagar, 1951 *b*), *Mimosa pudica* (Narasimhachar, 1951), *Neptunia triquetra* (Dnyansagar, 1952, 1954 *a*), *Desmanthus virgatus* (Dnyansagar, 1953), *Prosopis spicigera* (Dnyansagar, 1953, 1954 *a*) *Dichrostachys cinerea* and *Parkia biglandulosa* (Dnyansagar, 1954 *c*), *Acacia auriculæformis*, *Adenanthera pavonina* and *Calliandra hematocephala* (Dnyansagar, 1954 *b*, *c*) and *Mimosa hamata* where no suspensor is differentiated and (2) in the above plants of the Mimosaceæ, the basal cell *cb* does not contribute towards construction of the embryo proper and the tissue derived from it is homologous to the suspensor.

Souèges and Crété (1952) have classified the embryogeny of the plants that have been worked out in the Papilionaceæ under the "First and Second Periods". Under the Series B of the Megarchtype VI of the First Period, they have included the archtype *Trifolium minus* under *a* where the suspensor is well separated from the embryo and plants like *Genista*, *Ulex*, *Sarothamnus*, *Thermopsis*, *Dorycnium*, *Tetragonolobus*, *Colutea*, *Astragalus* and *Sesbania* under *b* where the suspensor is less distinct from the embryo proper.

Based on the above classification, the principal results obtained in the embryogeny of the Mimosaceæ can be presented briefly as follows:—

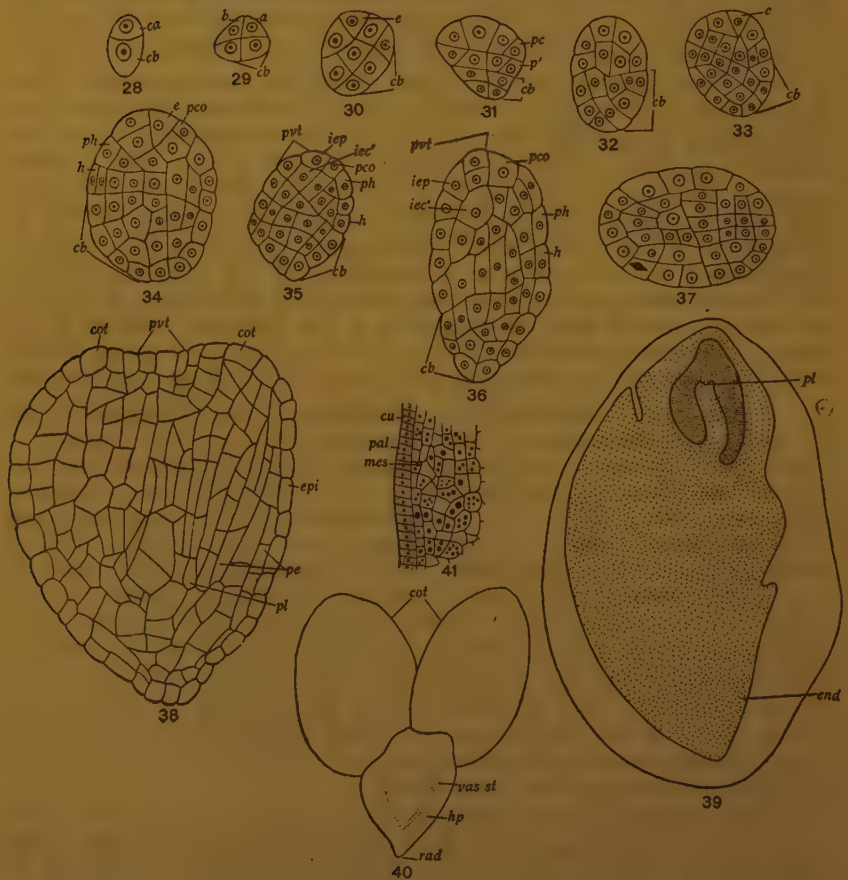
First Period

Series B (First tetrad of B_1 type usually)

Megarchtype VI

(*b*) Suspensor less distinct from the embryo—*Leucæna glauca.*

(*c*) No distinction between the suspensor and embryo—*Acacia, Mimosa, Pithecolobium, Neptunia, Prosopis, Desmanthus Dichrostachys, Parkia, Adenanthera* and *Calliandra.*



FIGS. 28–41. *Mimosa hamata*—Figs. 28–38. Various stages showing development of embryo. Legends same as for Figs. 14–25. Fig. 39. L.S. of developing seed showing advanced stage of embryo and cellular endosperm, *end. pl*, plumule. Fig. 40. Mature embryo. Legends same as for Fig. 26. Fig. 41. L.S. part of seed-coat. Legends same as for Fig. 27. Figs. 28–29, ×333·3; Fig. 40, ×17; Fig. 41, ×150.

Leucæna glauca has been included under (*b*) since the suspensor is less distinct from the embryo proper at least in early stages. The author thinks it necessary to divide the Series B further into (*c*) to include plants like *Acacia, Mimosa*, etc., where the proembryo is of the massive type and there is no line of demarcation between the suspensor and the embryo proper.

Seed-coat

The testa of the mature seed consists of both the integuments. Most of its cells contain brown pigments. It shows pleurogram (Corner, 1951) on each side. Its structure is shown in Figs. 27 and 41. It is almost similar to that described in the previously investigated species of the Mimosaceæ.

Summary

1. Development of the endosperm conforms to the Nuclear type. Cell-formation commences in the micropylar part of the embryo-sac and extends towards the chalazal region. The endosperm, however, remains free nuclear in the chalazal part even after the appearance of the cotyledons in the embryo and assumes a tubular form with a vesicular tip. This part acts as a haustorium till the formation of a barrier tissue by the nucellus.

2. The embryogeny is similar to the archtype *Trifolium minus* in broad outlines but in *Mimosa hamata*, there is no distinction between the suspensor and the embryo proper. In *Leucæna glauca*, the terminal part of the suspensor becomes filamentous in later stages.

The author has suggested further division of the Series B, Megarch-type VI of the First Period of Souèges for the inclusion of the plants of the Mimosaceæ showing the type of embryogeny that "lacks" a suspensor.

Acknowledgments

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FLUORESCENCE PHENOMENON IN FUSARIOSE WILT OF COTTON

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Fusarium vasinfectum Atk. infected cotton plants show vein clearing of cotyledonary leaves as the first visible symptom (Satyanarayana and Kalyanasundaram, 1952). Further work on symptomatology by Kalyanasundaram (1954), indicated the utility of starch test as a method in determining the probable path of movement of toxic metabolites of the pathogen inside the host. The present investigation was taken up with a view to explore the possibility of using ultraviolet illumination to study the etiology of cotton plants infected by *F. vasinfectum.*

Materials and Methods

Cotton plants (*Gossypium arboreum* race *indicum*) were infected with *Fusarium vasinfectum* Atk. (culture from Centraalbureau voor Schimmelcultures, Holland). Aqueous extracts of infected and healthy plants were made by grinding them against acid-washed sand which were later centrifuged and filtered. Neat culture filtrate of the pathogen was obtained by growing *F. vasinfectum* in Richard's synthetic medium for 3 weeks and dialysing the filtrate against distilled water at 4° C. The uninoculated Richard's medium served as control. Philips HPW 125 W, ultraviolet lamps with peak spectral energy at 3655 Å was used for all investigations. Ultraviolet light photographs were taken on HPS (Ilford) panchromatic plate using GR 5 (Yellow filter). For comparison, photographs were taken on HP 3 (Ilford) plate using ordinary incandescent lamps.

Results

An examination of infected plants under ultraviolet illumination in dark revealed characteristic fluorescence of stem and veins of leaves although infected plants examined at various stages of growth that show characteristic fluorescence do not always show visible vein clearing symptoms to the unaided eye or when photographed on panchromatic plates (Plate XV, Figs. 3 and 4). None of the healthy plants examined showed fluorescence (Plate XV, Figs. 1 and 2). The aqueous extracts of infected plants and the dialysed culture filtrate of the pathogen also fluoresced under ultraviolet light but the aqueous extracts of healthy plants and the uninoculated Richard's synthetic medium did not do so (Plate XV, Fig. 5). Microscopic examination of the transections of infected plants under ultraviolet light revealed characteristic fluorescence of the vascula region alone but no such phenomenon was seen in healthy sections.

Discussion

Fluorescence of stems and veins of cotton plants infected by *F. vasinfectum* under ultraviolet illumination has been shown here for the first time in a typical vascular wilt, although fluorescence has been reported in virus-infected plant tissues (Bawden, 1950) and other fungal and bacterial diseases of plants (Derrett-Smith, 1937; Minz, 1940; Flint and Edgerton, 1940; Odehnal, 1942). This phenomenon of fluorescence of stems and veins of infected plants has possibilities of screening infected plants of cotton under field conditions, for even incipient infection, invisible under daylight is visible under ultraviolet light. The observed fact presented here of the aqueous extract of infected cotton plants and the dialysed culture filtrate exhibiting fluorescence (Plate XV, Fig. 5) indicates that the *in vivo* toxin produced by the pathogen has optical properties similar to the culture filtrate. The most interesting observation presented here is the remarkable degree of fluorescence exhibited in the vascular region of the stem and roots of infected plants (Plate XV, Figs. 6 and 7). This is a confirmation of the true vascular nature of the disease and the tenability of the toxin theory of this disease (Gäumann, 1952; Lakshminarayanan, 1953). It must be mentioned here that the photographs of the section of the infected stem was taken with transmitted light but visual observations made using reflected ultraviolet light revealed under the low power of the microscope that fresh sections of infected stems show fluorescence mainly in the phloem region and to some extent in the walls of the xylem vessels. It is therefore likely that in the early stages of toxæmia, the phloem region exhibits fluorescence and in the advanced stage the xylem tissue may also progressively fluoresce. Further observations in this field are in progress.

Summary

Cotton plants grown in *Fusarium vasinfectum* infected soils, when examined under ultraviolet illumination, revealed characteristic fluorescence of stems and veins of leaves. The healthy plants grown in sterilised uninoculated soil, however, did not fluoresce.

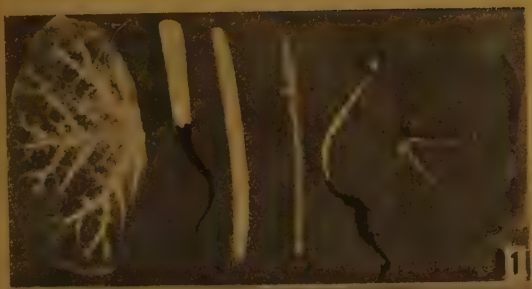
Aqueous extracts of infected cotton plants exhibited fluorescence *in vitro* similar to that of the dialysed culture filtrate of the pathogen responsible for the wilt of cotton.

Microscopic examination of transections of infected plants under ultraviolet light revealed characteristic fluorescence of vascular region only.

The probable cause for the fluorescence of stem and veins of infected cotton plants and the possibility of utilising it for screening infected plants under field conditions are discussed.

Acknowledgements

I am deeply indebted to Professor T. S. Sadasivan for guidance. Thanks are due to Dr. C. V. Subramanian and Dr. K. Ramakrishnan for reviewing the manuscript and to Dr. R. Kalyanasundaram for help.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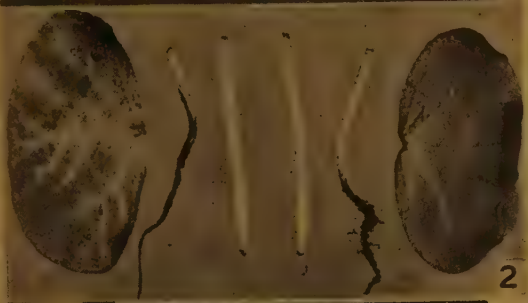
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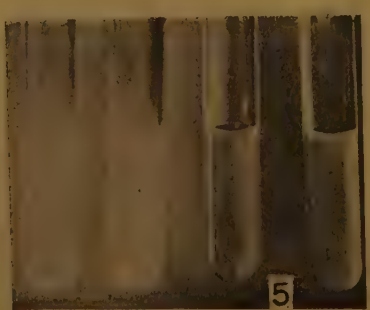
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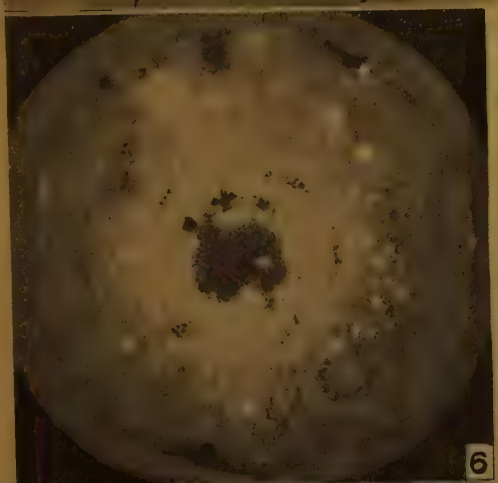
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* Original not seen.

Explanation to Figures (Plate XV)

FIGS. 1–7. Fig. 1. Ultraviolet light photograph showing cotyledonary leaf, the hypocotyl region and a portion of stem of infected cotton seedling (left) and a portion of stem, the hypocotyl region and cotyledonary leaf of healthy cotton seedling (right.) Fig. 2. The same specimens as in Fig. 1, under incandescent lamp. Fig. 3. Ultraviolet light photograph of stem, hypocotyl region and third leaf of an adult infected cotton plant showing distinct vein clearing and fluorescence of stem. Fig. 4. The same specimens as in Fig. 3, under incandescent lamp. Fig. 5. Left to right: Ultraviolet light photograph of aqueous extract of infected cotton seedlings, dialysed culture filtrate of *F. vasinfectum* (on Richard's synthetic medium as substrate), aqueous extract of healthy cotton seedlings and uninoculated Richard's synthetic medium. Fig. 6. Ultraviolet light photograph of transection of the stem of an infected cotton plant showing characteristic fluorescence in the vascular region. Fig. 7. Same section as in Fig. 6 under incandescent lamp.

ON A NEW SPECIES OF *HALICYSTIS* FROM SOUTH INDIA

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The alga forming the subject of this communication was collected by the authors at Krusadai Island near Pamban in the Gulf of Manaar in South India. It was found a little below low tide mark growing on *Lithothamnion* encrusting dead coral stones in the coral reef on the southern side of the island (Pl. XVI, Fig. 6). It generally grows on the more sheltered portions of the coral stones, such as the sides of the stones and also the crevices between the stones. The alga was growing sparsely and only a small number of specimens was obtained after a long search. As the alga is very minute and light green in colour and somewhat translucent, and often also covered by the larger algae, it easily escapes attention. It can be found only when the coral stones are taken out of the water and examined carefully, preferably with a hand lens.

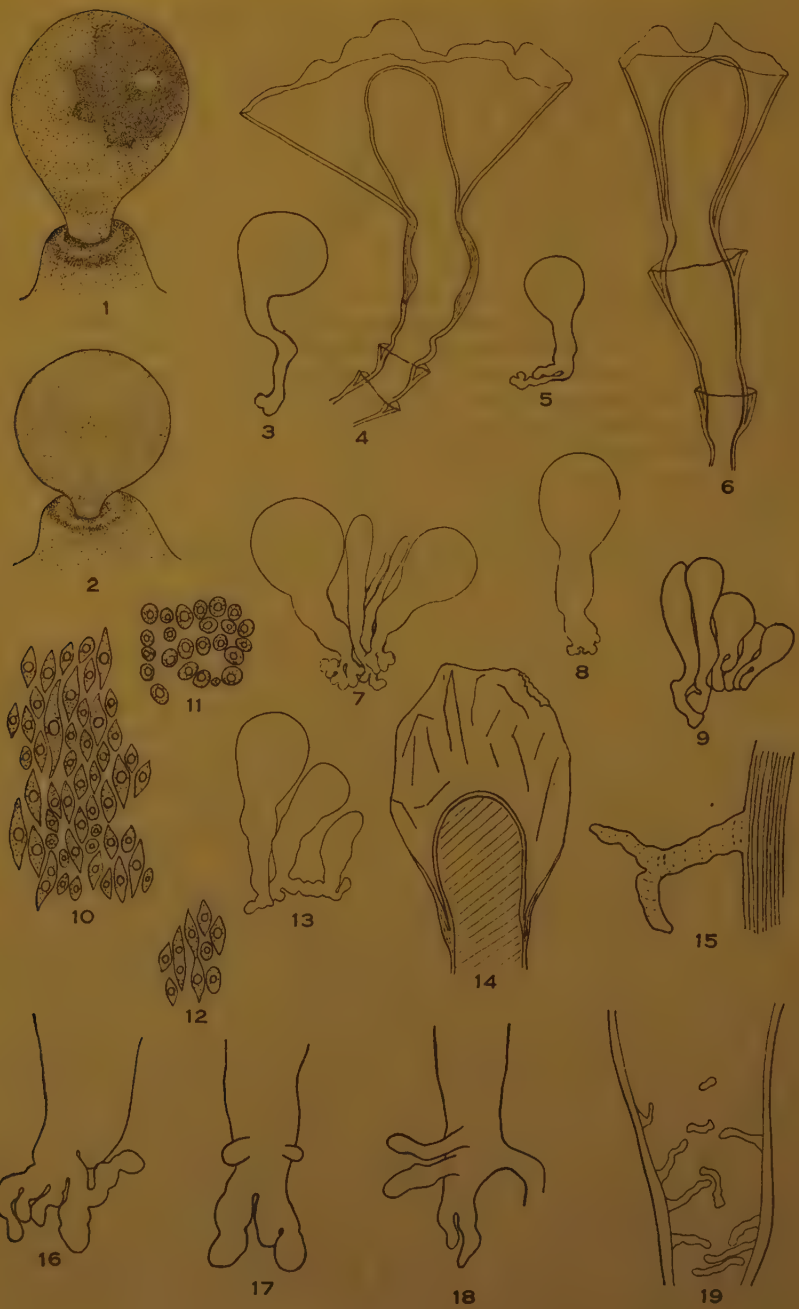
The alga is small and vesicular and is spherical to pyriform (Text-Figs. 1, 2, 3, 5, 7, 8; Pl. XVI, Figs. 1, 2, 3, 4, 8, 9, 11, 12). It is $\frac{1}{2}$–2 mm. in diameter when fully grown. The portion of the alga below the vesicle, *i.e.*, the portion which is embedded inside the *Lithothamnion*, was made out after decalcifying and carefully dissecting the *Halicystis* plants out of the *Lithothamnion* under a Greenough binocular dissecting microscope. The portion of the substrate (*Lithothamnion*) surrounding the uppermost portion of the stalk below the vesicle is slightly raised, so that the vesicle appears as if situated on the top of a tiny conical mound (Text-Figs. 1, 2). The vesicle has a long vertical colourless stalk or rhizome which is embedded in the host alga. This stalk is fairly broad in the upper portion, but becomes somewhat narrower towards its lower end (Text-Figs. 3, 5, 7, 8; Pl. XVI, Figs. 1, 2, 4, 11). The stalk is 150–250 μ thick and is 0·3–1 mm. long. At its lower end the stalk divides into two or more lobes (Text-Fig . 3, 5, 7, 8, 16, 17, 18; Pl. XVI, Figs. 4, 11, 12, 13) which may grow horizontally and branch again. Short thick irregularly swollen horizontal branches are also very frequently formed from the sides of the stalk a little above its lower end (Text-Figs. 13, 17, 18; Pl. XVI, Figs. 2, 4, 10, 13). From the upper portion of these horizontal branches are formed one or more cylindrical shoots which grow upwards and emerge from the *Lithothamnion* crust (Text-Fig. 13; Pl. XVI, Fig. 2). The end of each of these shoots after emerging out becomes gradually swollen into a round green vesicle, and these shoots become ultimately daughter-*Halicystis* plants. By means of this stoloniferous growth a number of daughter-plants may be formed around a parent individual. These daughter-plants remain connected with the parent plant for a short time, but soon

become independent by the breaking across the middle of the rhizomal connections between them. Owing to this close stoloniferous growth, the alga is very commonly seen in clusters. But, as the individuals of each cluster are of different ages, they vary very much in size (Text-Figs. 7, 9; Pl. XVI, Figs. 1, 2, 3, 14).

The vesicle contains a large vacuole in the centre, the protoplast forming a thin parietal layer. A number of nuclei and numerous chloroplasts are embedded in this lining layer of cytoplasm. The nuclei lie close to the wall, and the chloroplasts are a little below forming a more or less continuous layer. The chloroplasts are generally fusiform in shape in the lower and the middle portions of the vesicle (Text-Figs. 10, 12) but somewhat discoid in the upper portion (Text-Fig. 11). The fusiform chloroplasts lie with their longer axis more or less parallel with the longitudinal axis of the alga. Each chloroplast contains a single pyrenoid. Very occasionally two pyrenoids are seen in a chloroplast, but this appears to be a condition prior to the division of the chloroplast into two (Text-Fig. 12). The fusiform chloroplasts vary much in length. They are 7–24 μ long and 4–5·5 μ broad. The discoid chloroplasts are about 3–7 μ in diameter.

The cell wall is very firm and smooth and lamellated. It is thinner in the upper vesicular portion where it consists of 4–6 layers, but at the basal portion of the vesicle the wall is very much thicker and consists of a much larger number of layers, up to 10 or more. The cell-wall is 3·5–6 μ thick in the upper and the middle portions of the vesicle, and 15–23 μ thick in the lower portion of the vesicle. In the lower portion of the rhizome the wall is very thin. In the upper portion of the stalk a number of long cylindrical wall thickenings are seen projecting from the inner surface of the wall into the interior as recorded by Hollenberg (1935) in *H. ovalis*. These cylindrical thickenings are generally simple (Text-Fig. 19) but very often they are branched (Text-Fig. 15). The stalk and the rhizome portion are densely packed with chloroplasts and nuclei.

As the authors' stay on the island was very brief (about 3 or 4 days), no cultural experiments were attempted to study the periodicity of swarmer formation. They, however, placed a few pieces of *Lithothamnion* with some *Halicystis* plants on them in a small glass vessel filled with fresh sea-water, which was renewed at frequent intervals. In most of these vesicles, the protoplast became dark-green in colour and towards the evening began to accumulate as a dense mass towards the top of the vesicles (Text-Fig. 1). The accumulation became more and more dense in each vesicle and by about 10 P.M., a dark, more or less circular patch with a somewhat crenate margin was formed. In the centre of this dark patch a circular hyaline spot became visible indicating the place where the discharge of the swarmers will be taking place in the next morning as in *H. ovalis* (Smith, 1930, 1938; Hollenberg, 1935). Though the vesicles were kept under observation for a long time in the next morning, no discharge of the swarmers was seen. The culture conditions evidently were not satisfactory and so no discharge of the swarmers took place.



FIGS. 1–19

Text-Figs. 1–19. *Halicystis Boergesenii* sp. nov.—Fig. 1. A plant growing on *Lithothamnion*, showing the protoplast accumulated into a dark green round patch with a hyaline spot in the middle. Fig. 2. A smaller plant before the accumulation of the protoplast. Figs. 3, 5, 8. Plants showing vesicle, stalk and the branching of the lower end of the stalk into lobes. Figs. 4, 6. Regeneration of a vesicle from the upper end of the stalk. Note the wide funnel-like basal portion of the old mother-vesicle, and also two persisting funnel-like wall portions of previous vesicles. Figs. 7, 9, 13. Clusters of plants. Note in Fig. 13 the stoloniferous growth of new shoots from the upper side of a horizontal rhizomal branch. Figs. 10, 12. Chloroplasts at the lower portion of the vesicle. Note in Fig. 12, chloroplast with two pyrenoids. Fig. 11. Chloroplasts at the upper portion of the vesicle. Fig. 14. Regeneration of new vesicle inside the empty wall of the old vescicle. Figs. 16–18. Lower end of the stalk forming lobe-like branches. Fig. 15. A branched peg-like thickening growing inwards from the cell-wall. Fig. 19. Simple peg-like thickenings growing inwards from the cell-wall. Figs. 1, 2, ×25; Figs. 3, 5, ×16; Figs. 4, 6, ×60; Figs. 7, 8, 9, 13, ×22; Figs. 14, 16, 17, 18, ×42; Figs. 10, 11, 12, 15, ×500; Fig. 19, ×165.

Kuckuck (1907) states that the old vesicles in *H. ovalis* disappear just before the coming of winter, but does not say how the old vesicle is lost. Hollenberg (1935) states that the older vesicles are severed from the rhizome at a transverse line of abscission which develops in the wall at the base of the vesicle. The authors examined under high magnifications carefully all their material of the South Indian *Halicystis*, but in none of them could they see any indication of a transverse line of abscission in the wall at the base of the vesicle (Text-Figs. 4, 6). In two instances, on the other hand, they found a new vesicle regenerating inside the battered but *intact* empty wall of the old vesicle (Text-Fig. 14, Pl. XVI, Fig. 10). In other cases, the authors found that most of the upper portion of the old empty wall had disappeared, leaving only the lower portion of the empty wall persisting as a funnel-like collar round the regenerating new vesicle (Text-Figs. 4, 6; Pl. XVI, Figs. 5, 7). The reason for the disappearance of the contents of the old vesicle is not clear. Whatever may be the reason for the disappearance of the contents, a transverse wall more or less arched upwards, is seen already formed at the base of the empty vesicle. This wall bulges outwards into a new vesicle inside the empty wall of the old vesicle. It is only very rarely, as in the two cases mentioned above (Text-Fig. 14; Pl. XVI, Fig. 10), that the old empty wall persists intact for a long time, but usually most of the empty wall gets broken up by surf action and disappears leaving only the thicker and consequently the more resistant portion of the wall at the base intact as a funnel-like collar round the new vesicle. The rhizome portion of the alga appears to be perennial and evidently forms a new vesicle at the end of each season as in *H. ovalis* (Hollenberg, 1935). The rhizome portion of any old individual plant shows the persisting funnel-like basal portions of the walls of the several vesicles which had been previously formed by it. By counting the number of these persisting funnel-like walls or the scars left by them, one can form a rough idea of the number of times new vesicles have been regenerated by the stalk. Usually up to 6 funnel-like walls can be counted on a stalk. But in some individuals as many as 12 funnel-like walls can be counted. Again, these persisting funnel-like walls or the scars left by them are not all seen at the same level on the stalk (Text-Figs. 4, 6). This shows that the stalk continues to grow a little

upwards. This is evidently due to the fact that it has to keep pace with the upward growth of the host plant.

So far three species of *Halicystis* are known, *viz.*, *H. ovalis* (Lyngb.) Aresch., *H. parvula* Schmitz and *H. Osterhoutii* Blinks and Blinks. *H. ovalis* occurs in the North Sea and in the North American Pacific. The vesicular portion of this alga reaches a diameter of 1·6 cm. It has a short, erect colourless rhizome. The chloroplasts of this alga do not possess a pyrenoid.

Murray (1893, pp. 49–50) states that during the winter of 1879–80, Berthold called the attention of Schmitz to a *Halicystis* which was dredged in the Gulf of Naples. Schmitz referred this *Halicystis* to a new species, which he called *H. parvula*. Feldmann in 1929 found this alga in Algeria and at Banyuls, but referred the alga to *H. ovalis*. Later on, after a fresh examination of his specimens, he referred the alga to *H. parvula* as he found that it differed from *H. ovalis* in having pyrenoids in its chloroplasts, and also in having a very short stalk. He states that *H. ovalis* does not occur in the Mediterranean and that the forms recorded previously in the Mediterranean by various authors as *H. ovalis* are only *H. parvula*. He gives a short account of this species as follows: The alga forms small vesicles which are spherical or ovoid and reaches a diameter of 5 mm. It is fixed by a short pedicel which is more or less swollen at the extremity. The chloroplasts are ovoid or fusiform, and possess one, and at times, two pyrenoids. He (1937, p. 79, Fig. 22) also found at Banyuls a new form of *H. parvula* which he called f. *stipitata*. This form differs from the type in having its vesicle elongated into a stipe.

L. R. Blinks and A. H. Blinks (1930) have described a new species of *Halicystis* from Bermuda in the West Atlantic, which they called *H. Osterhoutii*. This alga was for a long time confused with *Valonia ventricosa* J. Ag. The vesicles in *H. Osterhoutii* are spherical to pyriform and reach a diameter of 3 cm., and are attached to the substratum by a narrow pedicel. Its chloroplasts possess one or more pyrenoids. These authors have expressed the opinion that *H. parvula* is very probably the same as *H. Osterhoutii*. But *H. parvula* is an extremely small species, its vesicles never exceeding 5 mm. in diameter, whereas *H. Osterhoutii* is a very large species whose vesicles reach a diameter of 3 cm. It would be better to keep these two species separate, until intermediate forms are found in *H. parvula* connecting it with *H. Osterhoutii*.

Coming to the present alga, it differs from *H. ovalis* in having pyrenoids in its chloroplasts. It resembles *H. parvula* and *H. Osterhoutii* in having pyrenoids in its chloroplasts and resembles the former species in its extremely small size also. But it differs from these two species in possessing a stalk which is branched at the lower end and particularly in its very characteristic stoloniferous growth. The alga is therefore referred to a new species. The authors have great pleasure in naming the alga *Halicystis Boergesenii* in honour of the eminent Danish algologist, Dr. F. Boergesen, who has done so much for Indian marine algology.

The distribution of *Halicystis* as at present known is the Eastern Atlantic and the Eastern Pacific (*H. ovalis*), the Mediterranean (*H. parvula*) and the Western Atlantic (*H. Osterhoutii*). So far there has been no record of the occurrence of this genus in the Indian Ocean (including the Bay of Bengal and the Arabian Sea) and in the Western and the Central Pacific. The occurrence therefore of the present *Halicystis* in South India is extremely interesting.

Description

Halicystis Boergesenii sp. nov.

Plants growing singly or in clusters. Vesicular portion spherical to pyriform, ½–2 mm. in diameter, light green in colour and somewhat translucent. Chloroplasts fusiform in the lower and the middle portion of the vesicle and more or less discoid in the upper portion. One, or occasionally two, pyrenoids in each chloroplast. Vesicle attached to the substratum by a long vertical rhizome which is branched into two or more lobes at its lower end. Daughter-*Halicystis* plants formed vegetatively from the lower portion of the stalk by stoloniferous growth.

Hab.—Epiphytic on *Lithothamnion* on coral reef, Krusadai Island near Pamban in the Gulf of Manaar in South India.

Halicystis Boergesenii sp. nov.

Huius speciei plantæ crescunt singulæ vel aggregatæ. Portio vesicularis sphærica vel pyriformis, 0·5–2 mm. diameter, pallide viridis aliquantulum translucens. Chloroplasta fusiformia in inferiore atque media parte vesiculæ, in superiore vero parte plus minusve discoidea. Pyrenoidea singula vel bina in singulis chloroplastis. Vesicula substrato fixa per rhizoma longum verticale in duas vel tres lacinias furcatum in parte infima. Novæ plantæ efformantur vegetative ex inferiore parte stipitis per incrementum stoloniferum.

Habitat epiphytice super *Lithothamnion* in cautibus corallinis, ad insulam Krusadai prope Pamban in "Gulf of Manaar" in India meridionali.

Summary

An account is given of a new species of *Halicystis*, *H. Boergesenii*, from South India. It grows on crusts of *Lithothamnion* on the coral reef on the southern side of Krusadai Island near Pamban in the Gulf of Manaar in South India.

The alga has a small vesicle about ½–2 mm. in diameter and has a vertical rhizome which may reach a length of up to 2 mm. The rhizome is branched at its extreme lower end. Some of the branches grow horizontally and give rise to new *Halicystis* daughter-plants by stoloniferous growth.

The vesicle portion dies out after a time, and then disintegrates and disappears. The rhizome portion, however, is perennial and, when the vesicle dies, a new vesicle is regenerated in its place from the

upper end of the stalk. In this way new vesicles are regenerated by the stalk for a number of seasons.

Discharge of gametes from the vesicle and sexual reproduction were not observed.

The genus *Halicystis* has been known so far only from the Eastern and the Western Atlantic, the Eastern Pacific and the Mediterranean. The occurrence of the present *Halicystis* in the Indian Ocean is therefore very interesting.

The authors' sincere thanks are due to Father H. Santapau for the Latin diagnosis of the new species.

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Explanation of Plate XVI

Halicystis Boergesenii sp. nov.

(Photomicrographs of formalin material teased out from the decalcified crusts of *Lithothamnion*)

Figs. 1, 2, 5, 6. Plants showing division of the stalk at its lower end into two or more lobe-like branches.

Figs. 3, 4, 11, 13. Small clusters of plants showing stoloniferous growth.

Figs. 7, 8. Larger clusters showing stoloniferous growth. Note the different sizes of the individuals in each cluster.

Fig. 11. A small cluster showing stoloniferous growth with a highly branched rhizomal portion. Note in the larger individual the development of a new vesicle from the upper end of the stalk inside the wall of the empty old vesicle.

Figs. 8, 10, 12. Upper end of the stalk growing out into a new vesicle with the persisting funnel-like basal portion of the wall of the old vesicle.

Fig. 14. Upper end of the stalk growing into a young vesicle inside the empty wall of the old vesicle.

Figs. 1, 2, 13, 14, ×30. Figs. 3, 4, ×33. Fig. 5, ×26. Figs. 6, 9, ×36. Fig. 7, ×23. Fig. 8, ×43. Figs. 10, 11, 12, ×53.


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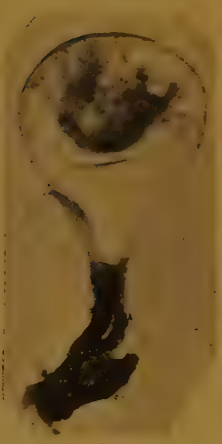
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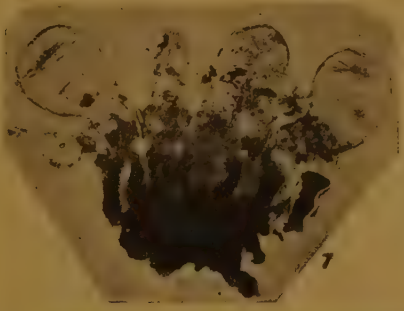
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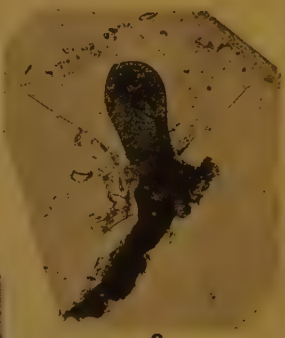
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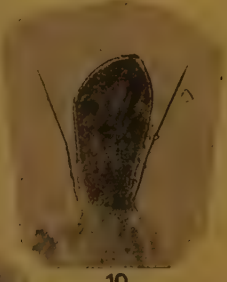
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EMBRYOLOGY OF *CRYPTOSTEGIA GRANDIFLORA* R.BR. AND *CARALLUMA ATTENUATA* WT.

By C. Venkata Rao and S. Rama Rao

Department of Botany, Andhra University, Waltair

(Received for publication on August 10, 1954)

As Asclepiadaceæ is the only family among dicotyledons, besides the Mimosaceæ, in which pollen occurs in packets, it attracted the attention of embryologists quite early. In spite of this, the embryological studies on the family which comprises 320 genera and 1,800 species, are relatively limited and cover only a few forms. There is practically no complete account of all phases of life-history of even a single species. Gager (1902), Schnarf (1931) and Sabet (1931) have given a review of the previous work. Since then Richaria and Nirula (1945) have investigated the microsporogenesis in *Hemidesmus indicus* and Nirula (1945) has studied the cytology and embryo-sac development in *Dæmia extensa*. Pierre Crete (1950) has described the embryo development in *Asclepias curassavica*.

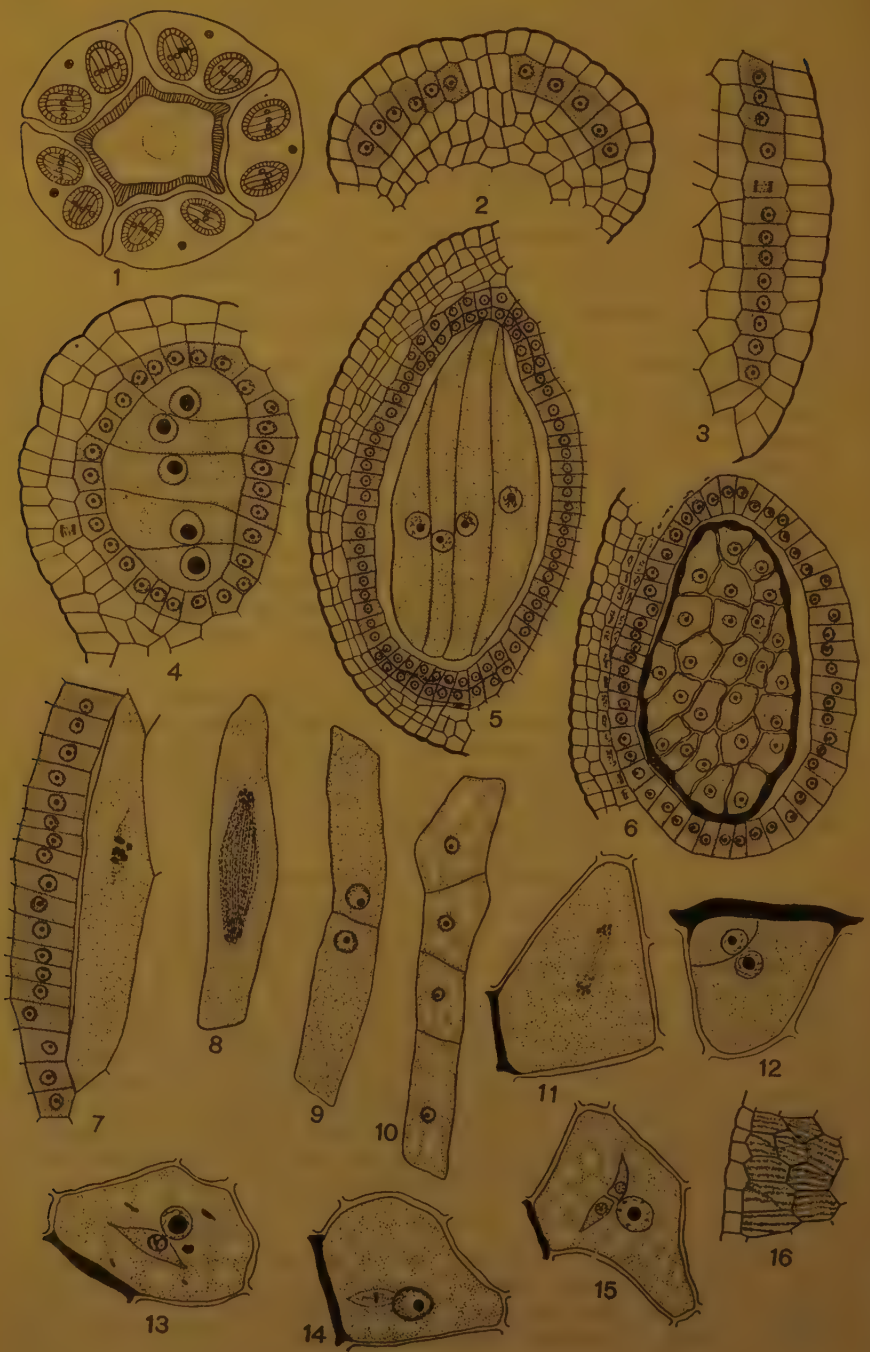
This article deals with the development of the anther, translator, microsporogenesis, development of the male gametophyte, ovule, embryo-sac, endosperm, embryo and seed of *Cryptostegia grandiflora* R. Br. belonging to Periplocoideæ in which pollen occurs in tetrads and *Caralluma attenuata* Wt. (= *C. fimbriata* Hook.) of Cynanchoideæ in which pollinia are found.

Materials and Methods

Cryptostegia grandiflora is a shrubby twiner which grows wild in several parts of Andhra. It sprang into prominence during the last war as an emergency source of rubber. Material of this plant was collected from plants growing at Waltair and Masulipatam. *Caralluma attenuata* is a succulent leafless herbaceous weed growing on the hillocks of Waltair. The material was fixed in formalin-acetic-alcohol. The perianth was removed from the older flower buds before fixation. Developing fruits were cut into bits to facilitate rapid penetration of the fixative and the seeds were fixed separately. Customary methods of microtechnique were followed and the preparations were stained in Harris' and Delafield's hæmatoxylin.

Flowers

The large flowers of *Cryptostegia grandiflora* occur in dichasial cymes with monochasial tendency. Some branched glandular structures arise on the thalamus between sepals (Figs. 22, 23). These are lined by radially elongated richly protoplasmic cells (Fig. 24) which



FIGS. 1–16

FIGS. 1–16. *Caralluma attenuata*. Fig. 1. Transverse section of gynostegium, ×45. Figs. 2. and 3. T.S. and L.S. of anther primordia respectively, showing archesporium, ×340. Fig. 4. T.S. of young anther lobe showing sporogenous cells, tapetum and wall layers, ×100. FIG. 5. T.S. anther lobe with full grown sporocytes, ×135. Fig. 6. T.S. anther lobe with pollinium; note uninucleate condition of tapetal cells, ×135. Figs. 7–10. Formation of microspore tetrad, ×285. Figs. 11–15. Development of male gametophyte, ×340. Fig. 16. Part of the anther wall showing multiseriate tapetum, ×195.

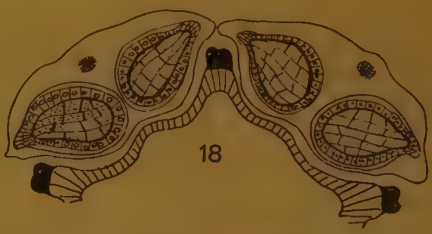
are probably concerned in secretion of honey. The stamens show hood-like outgrowths from connectives, though they are less prominent than those of Annonaceæ. One erect spoon-shaped translator is present on the stigmatic ridge between every pair of anthers, with its adhesive disc below. The ovary is bicarpellary, with numerous ovules in each carpel on swollen placentæ (Figs. 81, 82).

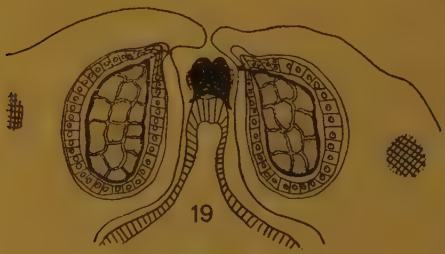
The flowers of *Caralluma attenuata* are confined to the upper nodes. They are provided with pentamerous perianth, a short staminal column and two carpels in which the ovules occur in two marginal rows (Fig. 59). The placenta is not swollen in this species. A wing-like outgrowth arises on the placenta and grows along with the ovules till the time of fertilisation (Figs. 60–64), after which it persists as a membraneous structure in the fruit.

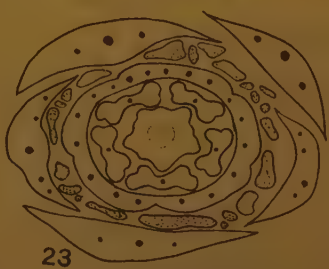
MICROSPOROGENESIS

In *Cryptostegia*, the anthers are 4-locular as in Apocynaceæ (Fig. 25), while those of *Caralluma* are 2-locular (Figs. 1, 18). This difference, which Richaria (1934) also found consistently among the genera belonging to the two sub-families he studied, seems to be associated with the difference in the type of translator mechanism. The anthers of *Caralluma* appear elliptic in t.s. (Fig. 2) while those of *Cryptostegia* (Fig. 25) are 4-angular. The archesporium, in both the species, has the shape of a plate of hypodermal cells. In *Caralluma* it differentiates at 2 places and is 5–6 cells wide (Figs. 2, 4, 5). In *Cryptostegia* it differentiates at 4 places and is 10–12 cells wide (Fig. 27). It is several cells deep as can be seen in longitudinal sections (Figs. 3, 26). The archesporial cells divide periclinally forming the primary sporogenous cells to the inside and the primary parietal cells to the outside (Figs. 3, 26). The inner layer of wall cells derived from the periclinal division of the primary parietal cells directly organises into the tapetum (Fig. 27). By further divisions in the outer layer, the anther wall becomes 2–3 layered below the epidermis. The epidermis of the mature anther consists of tangentially flattened cells. The sub-epidermal layer in *Cryptostegia* forms the uniseriate endothecium (Figs. 31, 32). In *Caralluma*, the fibrous thickenings develop in deeper layers of cells also so that the endothecium in this genus becomes multiseriate (Fig. 16). A similar condition has been reported by Swamy (1949) in Orchidaceæ. The remaining wall layers get crushed.

In both species studied, the tapetum is of the secretory type as in the Apocynaceæ (Anantaswamy Rao, 1940). In this respect it differs from Gentianaceæ and Loganiaceæ (Schnarf, 1931) in which it is amœboid. The tapetum shows interesting differences in the two species







FIGS. 17–27

FIGS. 17–21. Development of translator in *Caralluma attenuata*. Fig. 17. Cells of the ridge of stigma, ×195. Figs. 18–20. Formation of corpusculum and cuticle around the pollinium, ×45. Fig. 21. A fully formed translator, ×45.

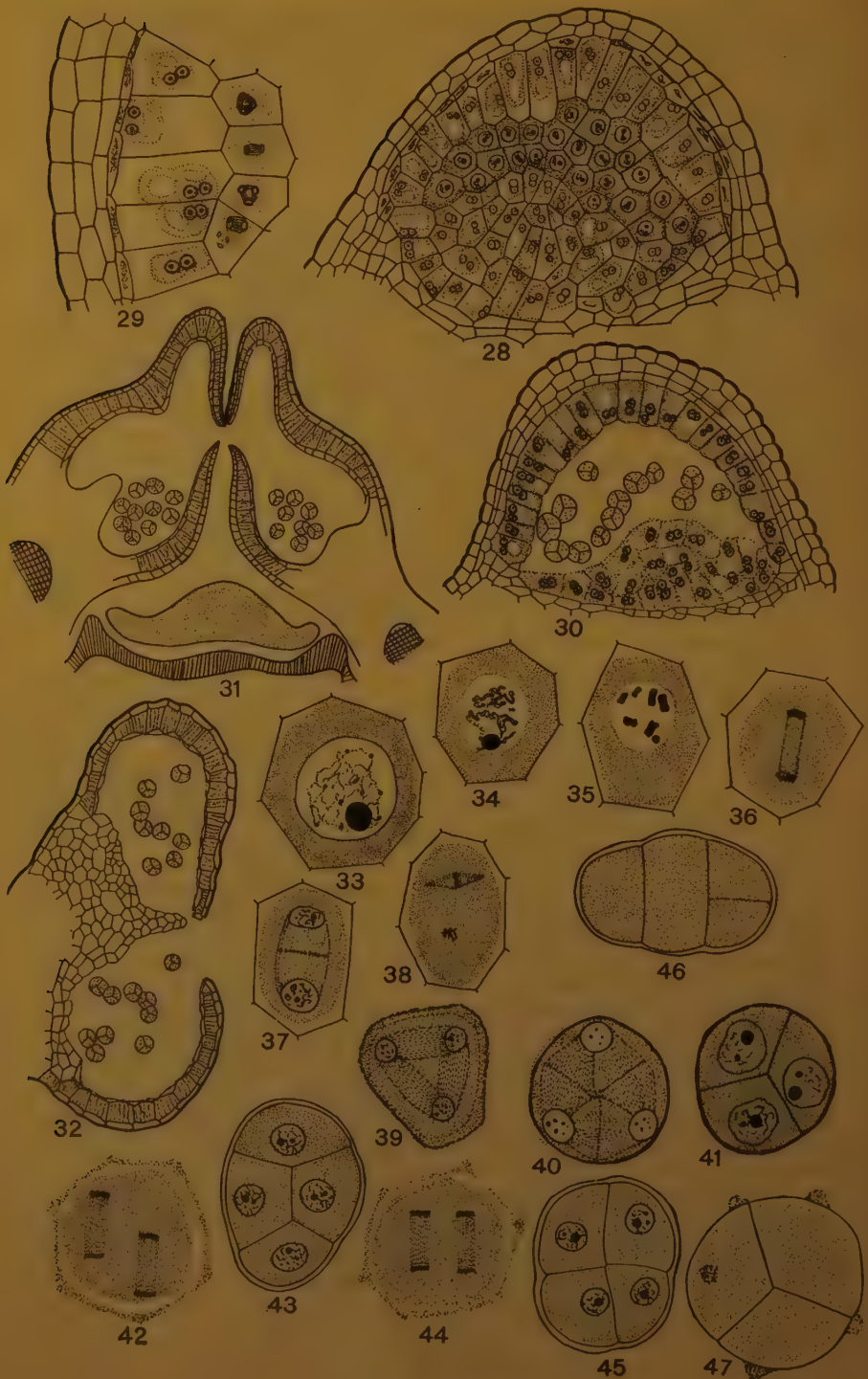
FIGS. 22–27. *Cryptostegia grandiflora*. Figs. 22 and 23. T.S. of flower bud at level of ovary and gynostegium respectively; dotted structures are the nectaries, ×10. Fig. 24. T.S. of the nectary, ×195. FIG. 25. T.S. of gynostegium, ×45. Figs. 26 and 27. L.S. and T.S. of anther primordia respectively, showing archesporium and formation of parietal layers, ×340.

studied. The tapetal cells in *Caralluma* stain deeper than the sporogenous cells at all stages of development, while in *Cryptostegia* they stain lighter. In *Caralluma* the tapetum is mostly uniseriate. In *Cryptostegia*, the mass of sporogenous cells appears reniform in t.s. All the cells of the connective situated in the concavity of the sporogenous mass function as the tapetum, so that it is multiseriate in this region (Figs. 28, 30). The tapetal cells in *Cryptostegia* become binucleate during prophase I of the sporocytes (Figs. 28–30). On the other hand, they remain 1-nucleate all through in *Caralluma* (Figs. 4–7). In Apocynaceæ also Anantaswamy Rao (1940) noticed uninucleate cells in *Rauwolfia*, *Vinca*, etc. It is interesting to find that in Orchidaceæ also, both types of tapetal cells are seen: uninucleate in Monandreæ and 2-nucleate in Diandreæ (*Paphiopedilum*, Swamy, 1949). The cytoplasm of the tapetal cells in *Cryptostegia* is relatively scanty and vacuolated. After the formation of the pollen tetrads, the walls of the tapetal cells in the concave region of the loculus become extremely delicate so that the mass looks like a plasmodium (Fig. 30). Remnants of the tapetal cells persist till the pollen grains are nearly mature.

The primary sporogenous cells in *Caralluma attenuata* function directly as the spore mother cells (Figs. 2, 4, 5), as Frye (1901) and Gajer (1902) noticed in *Asclepias*, and Nirula (1945) in *Dœmia*. In *Cryptostegia*, on the other hand, they undergo a periclinal division simultaneously with the division of the primary parietal layer and usually become biseriate (Fig. 28). While the pollen mother cells in *Cryptostegia* are small and almost isodiametric (Figs. 28, 29), those of *Caralluma* are much elongated (Figs. 4, 5, 7).

In *Caralluma attenuata*, the two meiotic divisions proceed in a successive fashion (Figs. 7–10) and synchronously in all the sporocytes of a loculus. The spindle is intranuclear in origin (Fig. 7) and is always laid parallel to the long axis of the cell. At the end of the first division, cell division occurs by cell plate formation (Fig. 9). Microspore tetrads are always linear in this species. This arrangement seems to be adapted to resist the tensile pull that is exerted consequent upon the extraction of the pollinium by the insect visitor. The parent cell wall persists and invests part of each microspore. At first, the microspores are rectangular and arranged in regular linear series, but later they change in shape and position due to the rounding up of the pollinium and mutual pressure of the cells.

The two meiotic divisions in *Cryptostegia* proceed in a simultaneous manner. It resembles in this respect, members of Apocynaceæ (Anantaswamy Rao, 1940; Tackholm and Soderberg, 1918). Due to differences in orientation of the spindles in the second meiotic division,



FIGS. 28–47

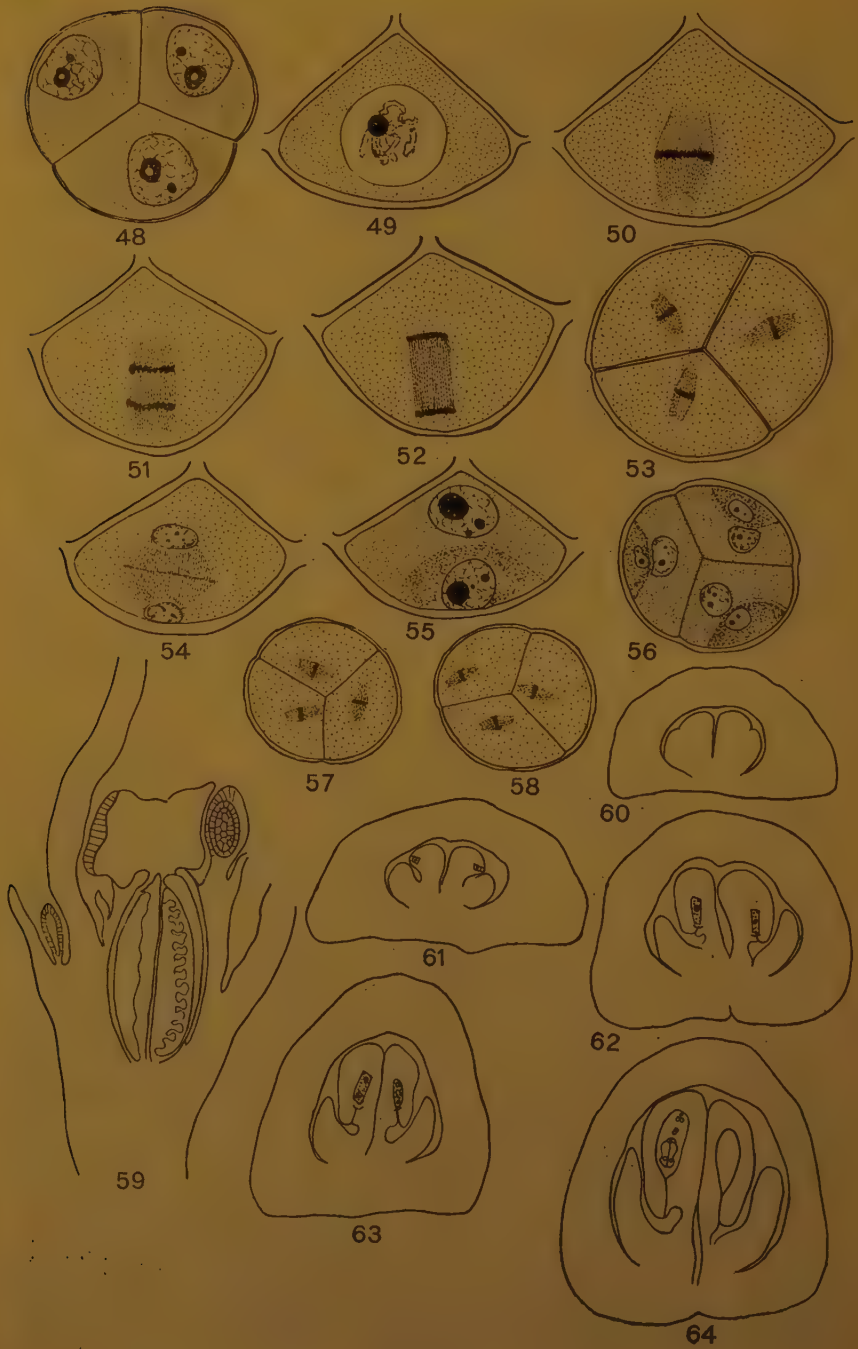
Figs. 28–47. *Cryptostegia grandiflora.* Fig. 28. T.S. of part of anther lobe with tapetal cells and sporocytes, ×195. Fig. 29. T.S. of anther lobe showing binucleate tapetal cells and sporocytes in meiosis, ×340. Fig. 30. T.S. of older anther lobe with spore tetrads, ×160. Fig. 31. T.S. of part of the gynostegium with two anthers and translator, ×130. Fig. 32. A dehisced anther, ×130. Figs. 33–46. Stages in development of the microspore tetrads, ×715. Fig. 47. A spore tetrad with oily secretion on the exine, ×715.

different types of microspore tetrads result: tetrahedral (Figs. 39–41), bilateral (Figs. 44, 45), T-shaped (Fig. 46) and intermediate types (Figs. 42, 43), as Joshi and Pantulu (1941) also found in *Polianthes tuberosa.* There is a distinct interphase during which an evanescent cell plate is formed (Fig. 37). The meiotic divisions in the sporocytes of a loculus, unlike in *Caralluma,* do not proceed synchronously. There is greater disparity in the division of the sporocytes in the different loculi of the anther: the sporocytes in one loculus may be in prophase I when in another, they may have already formed microspore tetrads. Cytokinesis takes place by cell plate formation (Fig. 40, 41). In this respect *Cryptostegia* differs from Apocynaceæ (Anantaswamy Rao, 1940) in which it is brought about by furrowing. The only exception to this rule in the family so far known appears to be *Rauwolfia canescens* (Meyers, 1938) in which cytokinesis by cell plate formation is reported. Towards the end of telophase I, the wall of the microsporocytes gelatinises and the developing tetrads separate. In due course the exine is secreted. Both species are markedly protandrous. Pollen tetrads are already formed when the ovules in the same flower show the megaspore mother cell stage.

Male Gametophyte

The cytoplasm of the microspore in most angiosperms, becomes bag-like by the development of a big vacuole by the time the microspore nucleus divides. However, in both species studied, during the course of the present investigation, it does not show such vacuolation. A similar condition was found by Swamy (1949) in Orchidaceæ. The generative cell in *Caralluma* varies slightly in shape from hemispherical to lenticular, depending upon its location, whether it is against a flat side or corner of a cell (Figs. 11, 12). Its cytoplasm is denser than that of the vegetative cell. The outline of the cell remains distinct even after it migrates into the vegetative cytoplasm. At first it is elliptic, but its ends later on become pointed (Fig. 13), though they are not so elongated as Finn (1925) described in *Asclepias cornuti.* Some extra nuclear bodies of a proteinaceous nature are noticed in the vegetative cytoplasm (Fig. 13). The generative cell divides (Fig. 14) to form two male cells, which appear triangular in section (Fig. 15). The pollen grains are 3-celled at the time of pollination.

The pollen tetrads in *Cryptostegia* remain intact till the time of shedding. Nuclear divisions in all the microspores of a tetrad proceed synchronously (Figs. 53, 57, 58). The metaphase and anaphase spindles are symmetrical and show truncated poles (Figs. 50, 51). The lenticular generative cell is always formed against the free wall of the microspore (Figs. 52–56). However, a few cases were noticed in which the



FIGS. 48–64

FIGS. 48–58. *Cryptostegia grandiflora*. FIGS. 48–56. Stages in the development of male gametophyte. Figs. 48, 53 and 56, ×715; rest, ×1,070. Figs. 57 and 58. Different orientation of the spindles in the first division of the microspore nucleus in the microspores of the same tetrad, ×340.

FIGS. 59–64. *Caralluma attenuata*. Fig. 59. L.S. of flower bud showing gynostegium, and arrangement of ovules, ×15. Figs. 60–64. T.S. of carpel at different stages of development, ×75.

spindles in all the microspores of a tetrad were not oriented in a similar manner (Figs. 57, 58). In these cases, the generative cell in the different pollen grains of a tetrad varies in position. A similar abnormal tetrad was described by Joshi and Venkateswarlu (1936) in *Nesæa myrtifolia*. The exine of the mature pollen grain is smooth and appears granular in surface view. Sometimes an oily secretion accumulates on the exine in the shape of fine globules (Fig. 47).

The development of the translator was followed in *Caralluma attenuata* (Figs. 17–21). The stigma is angular in outline and the ridges fit into the depressions among the anthers (Fig. 1). The epidermis of the stigma consists of radially elongated and richly protoplasmic cells. Gradually the cells on the ridge between the stamens become more columnar and their nuclei more ellipsoidal (Fig. 17). As the meiotic divisions proceed, the cells in the upper part of the ridge divide periclinally and form a layer of cells to the outside. These gradually lose their cellular nature, become hard and cartilaginous and form the corpusculum. The formation of the corpusculum commences earlier than the formation of the cuticle around the pollinium (Fig. 18). The cuticle develops on the wall separating the mass of pollen grains from the tapetum. The tapetal cells remain intact till this time without showing any sign of degeneration (Figs. 18, 19). The tapetum, from now onwards, degenerates rapidly as the cuticle thickens, showing thereby that it is consumed in this process (Fig. 20). In the part of the anther which is nearest to the corpusculum, a pocket-like depression is formed by the breakdown of the tapetal cells and a stomium is organised in this region. The cuticle around the pollinium extends in a filiform manner through the stomium and attaches itself to the corpusculum forming the translator. In *Cryptostegia*, the translator is erect and spoon shaped. The two loculi of each anther lobe coalesce in the mature anther and dehisce along a well-defined stomium (Fig. 32). The pollen tetrads from adjacent anther lobes are shed into the spoon (Fig. 31).

OVULE

The ovules are anatropous and provided with single massive integument as in other Sympetalæ. The ovules in the median region of the ovary lie transverse to the ovarian axis (Figs. 81, 82) while those in the upper and lower regions of the loculus are variously inclined. This arrangement gets disturbed after fertilisation and developing seeds lie parallel to the placenta.

The primordium of the integument differentiates simultaneously with the archesporium (Figs. 65, 83). The integument closes to form the micropyle even before the megaspore mother cell forms the tetrad

FIGS. 65–80

FIGS. 65–80. *Caralluma attenuata*. Fig. 65. Ovule primordium showing archesporium, ×340. Fig. 66. Ovule with full grown megaspore mother cell, ×340. Figs. 67 and 68. Nucellus with megaspore mother cell, ×715. Fig. 69. Nucellus with dyad, ×340. Fig. 70. Ovule with megaspore tetrad, ×235. Figs. 71–74. Stages in the development of 2-nucleate embryo-sac, ×340. Fig. 75. Ovule with 2-nucleate embryo-sac, ×235. Fig. 76. Young embryo-sac, ×715. Fig. 77. Mature embryo-sac, ×450. Fig. 78. Ovule with mature embryo-sac, ×235. Fig. 79. Upper part of mature embryo-sac, ×715. Fig. 80. Lower part of embryo-sac showing antipodals with synergid-like vacuolation, ×715.

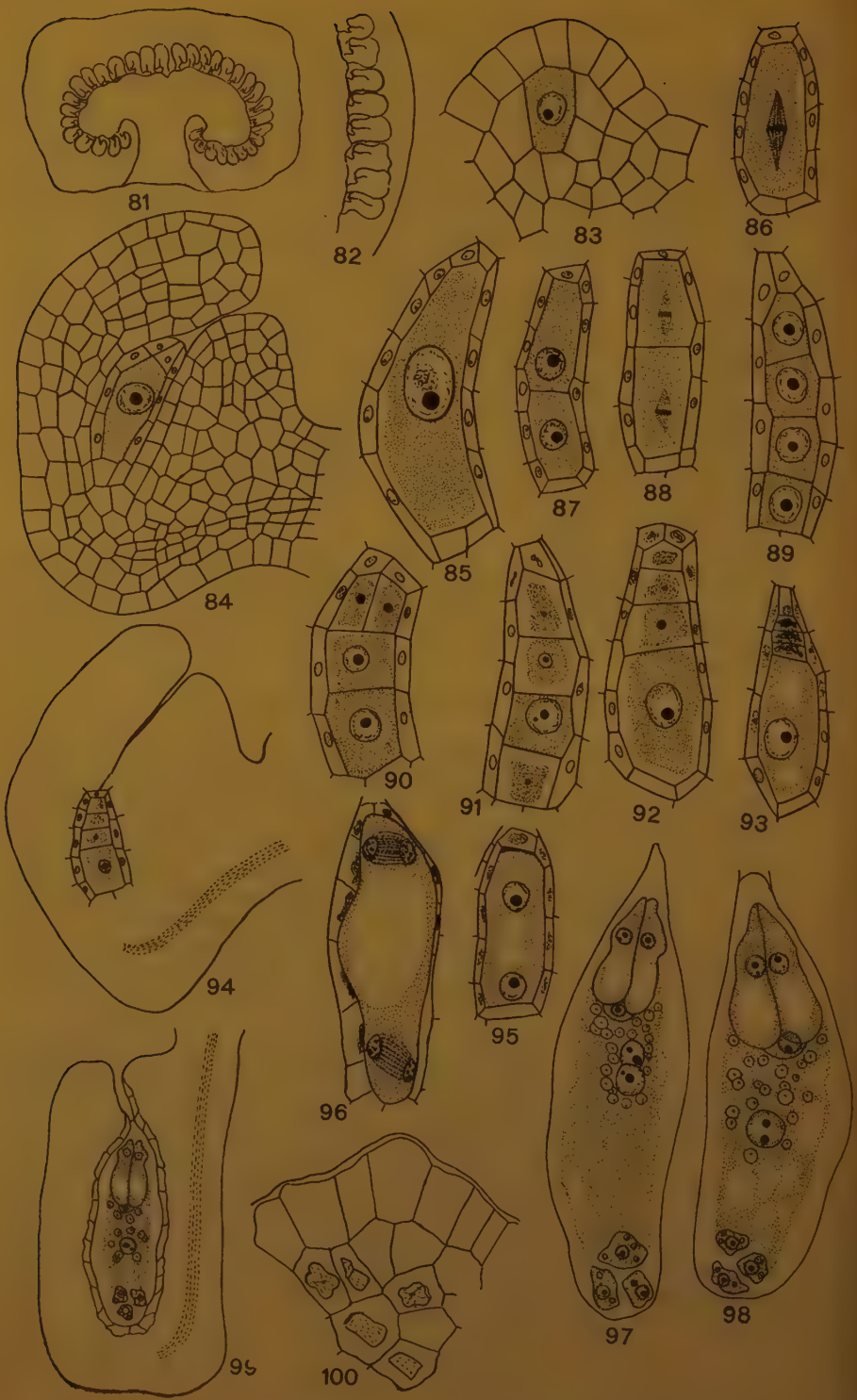
(Figs. 66, 84). In course of time the micropyle becomes a long narrow tube (Figs. 70, 75, 78, 94, 99). The integument of a fertilisable ovule of *Caralluma* is 4–5 layered, while it is 6–7 cells thick in *Cryptostegia*. Unlike in most Sympetalæ, an integumentary tapetum is not organised. In this feature resemblance is seen to genera of Apocynaceæ like *Wrightia*, *Vallaris*, *Funtumina*, etc. (Anantaswamy Rao, 1940). In *Amsonia* and *Rhazya* (Anderson, 1931) of Apocynaceæ and *Polyspermum procumbens* of Loganiaceæ (Moore, 1948), however, an endothelium is seen. The ovules of *Caralluma attenuata* show a blunt chalazal outgrowth (Fig. 78).

The nucellus is scanty and consists of a single layer of tangentially flattened cells surrounding the megaspore mother cell. These get crushed at about the 4-nucleate stage of the embryo-sac (Fig. 96), and the embryo-sac borders on the inner epidermis of the integument (Fig. 99).

MEGASPOROGENESIS AND EMBRYO-SAC

The archesporium in both the species consists of a single hypodermal cell which functions directly as the megaspore mother cell and does not cut off a parietal cell. The full grown megaspore mother-cell is either straight (Fig. 66), or slightly curved (Figs. 67, 85), and has its nucleus either at the middle (Figs. 68, 85) or towards the micropylar end (Fig. 67). The two meiotic divisions proceed normally (Figs. 69, 86, 87, 88), and result usually in a linear tetrad (Figs. 70, 71, 72, 89, 91–94), but a T-shaped tetrad has also been noticed in *Cryptostegia* (Fig. 90). The chalazal megaspore functions and forms the embryo-sac according to the *Normal*-type. In one case, in *Cryptostegia*, the third megaspore from the micropylar side was seen to be enlarging (Fig. 91).

The two polar nuclei meet at the middle of the sac and fuse before fertilisation (Figs. 76, 78, 97, 98). The two synergids are hooked and show two terminal vacuoles (Figs. 77, 98). Filiform apparatus described by Nirula (1945) in *Dæmia extensa*, was not noticed in the present studies. Starch grains are present in the egg of *Caralluma attenuata* and the antipodals and embryo-sac of both species. The antipodals in *Caralluma* sometimes are elongated and show snyergid-like vacuolation (Fig. 80) as Pardi (1934) noticed in *Asclepias curassavica*. The cells of the placenta in *Cryptostegia grandiflora* show abundance of plate-like crystals of calcium oxalate (Fig. 100).



FIGS. 81–100

FIGS. 81–100. *Cryptostegia grandiflora*. Figs: 81 and 82. T.S. and L.S. of ovary showing placenta and arrangement of ovules, ×15. Fig. 83. Ovule primordium with archesporium, ×715. Fig. 84. Ovule with full grown megaspore mother cell, ×340. Figs. 85–89. Formation of linear tetrad, ×715. Fig. 90. T-shaped tetrad, ×715. Fig. 91. A linear tetrad with the third megaspore enlarging, ×715. Figs. 92 and 93. Formation of 1-nucleate embryo-sac, ×715. Fig. 94. Ovule with linear tetrad, ×235. Figs. 95 and 96. Two- and four-nucleate embryo-sacs, ×715. Fig. 97. Young embryo-sac, ×450. Fig. 98. Mature embryo-sac, ×395. Fig. 99. Ovule with mature embryo-sac, ×235. Fig. 100. Cells of placenta with crystals of calcium oxalate, ×395.

FERTILISATION

Since the honey in the flowers of *Cryptostegia grandiflora* is exposed, ants also visit the flowers. When flowers showing signs of withering are opened, some ants are found inside struggling with the adhesive discs of translators attached to their abdomens. So they seem to be helpful in pollination.

Fertilisation is porogamous. Usually one (Fig. 101), but occasionally two (Fig. 102) pollen tubes enter the micropyle of an ovule. The pollen tube penetrates one synergid and empties its contents therein. Remnants of the affected synergid might persist upto the 5-celled stage of the embryo (Fig. 109).

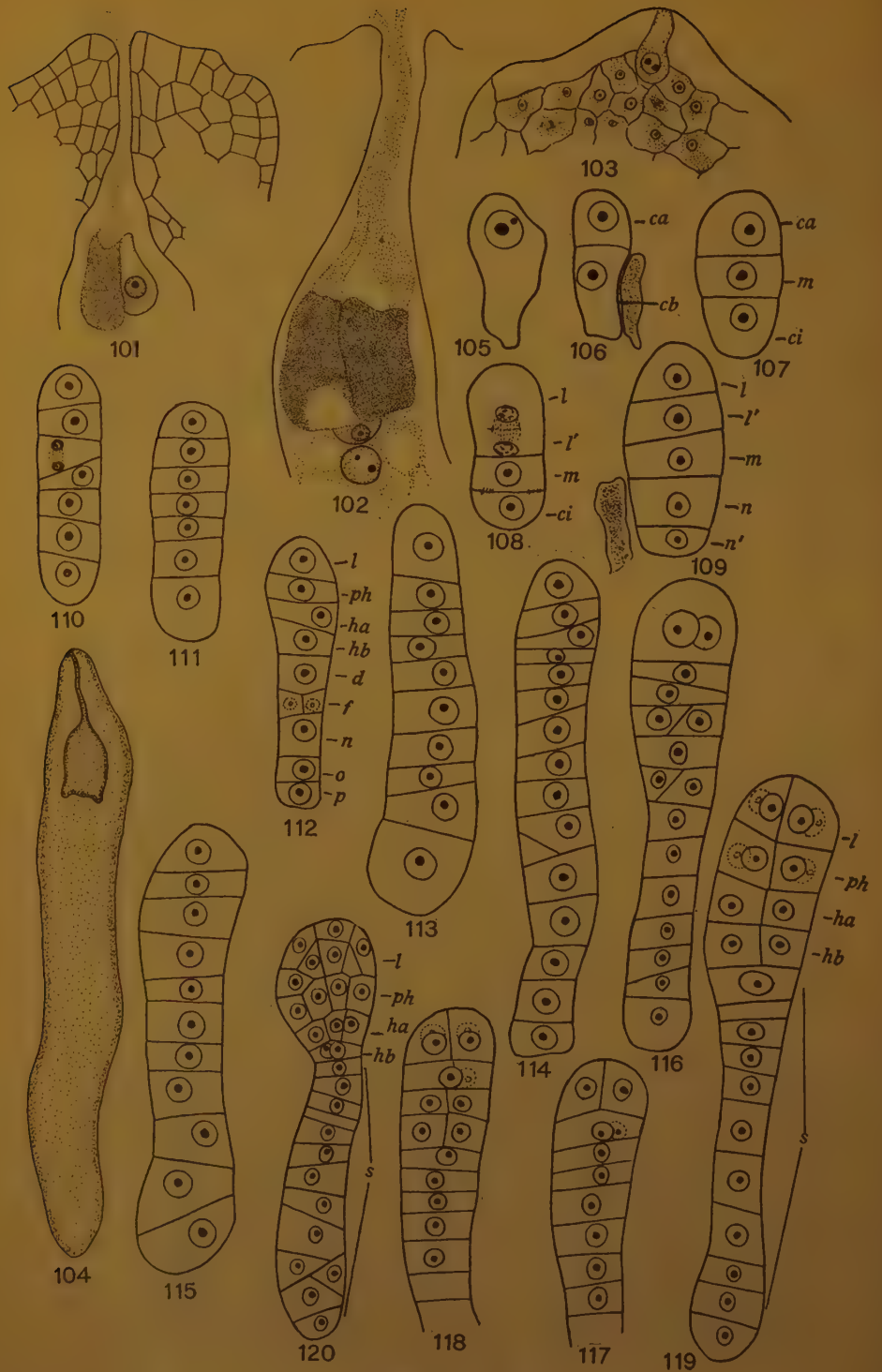
ENDOSPERM

Endosperm is nuclear (Figs. 126, 133). The primary endosperm nucleus divides much earlier than the fertilised egg (Fig. 133). Cell wall formation commences at 16–32 nucleate stage. In *Cryptostegia*, the post-fertilisation growth of the embryo-sac is considerable and the endosperm in the early stages forms a peripheral layer. The central cavity gets filled only in the advanced stages of seed development (Fig. 104). In *Caralluma attenuata*, on the other hand, the sac does not expand much and is filled with endosperm from the early stages (Fig. 127). The cells of the outermost layer of endosperm are more densely cytoplasmic and radially elongated, while the inner ones are tangentially flattened or possess an irregular shape (Fig. 127). Some deep staining proteinaceous granules are noticed in the outer layer of cells. All cells are uninucleate. Three or four layers of endosperm cells surround the mature embryo.

EMBRYO

Due to prevalence of sterility in *Caralluma attenuata*, only a few stages in embryo development could be observed. In *Cryptostegia grandiflora*, however, the embryo development has been followed more closely and is seen to conform to the *Linum*-variation of the Solanad Type. Formation of a linear proembryonic tetrad is the chief characteristic of the Solanad Type, and the presence of an elongated suspensor whose cells are not haustorial distinguishes the *Linum*-variation (Johansen, 1950). The details of embryogeny agree with those of *Asclepias curassavica* (Crete, 1950) and *Lobelia amœna* (Hewitt, 1939).

The fertilised egg (Figs. 103, 105, 126) divides transversely and forms *ca* and *cb* (Fig. 106). Usually both cells undergo transverse divisions simultaneously forming a linear tetrad in which the cells are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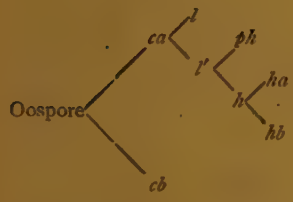
FIGS. 101–120

FIGS. 101-120. *Cryptostegia grandiflora*. FIGS. 101 and 102. Micropylar part of ovule penetrated by one and two pollen tubes respectively, ×220. Fig. 103. Upper part of ovule showing fertilised egg surrounded by endosperm which has become cellular, ×285. Fig. 104. Embryo-sac with large embryo and endosperm, ×45. Figs. 105–120. Stages in the development of embryo, ×715.

designated *l*, *l'*, *m* and *ci* (Fig. 108). Sometimes, division in *cb* precedes that in *ca* (Fig. 107). As the first divisions in *l* are vertical, it forms a single tier which develops into the stem tip and cotyledons. *l'* undergoes transverse division and forms *ph* and *h* (Figs. 111–115, 130). Later, *h* divides transversely and gives rise to *ha* and *hb* (Figs. 114, 117). Divisions in *m* and *ci* are mostly transverse and the derivatives which are termed *d*, *f*, *n*, *o*, *p*, etc., build up the suspensor. The suspensor is longer in *Cryptostegia* than in *Caralluma*. The embryonal mass is 4-tiered and the destination of the tiers is represented in the following table:

TABLE I



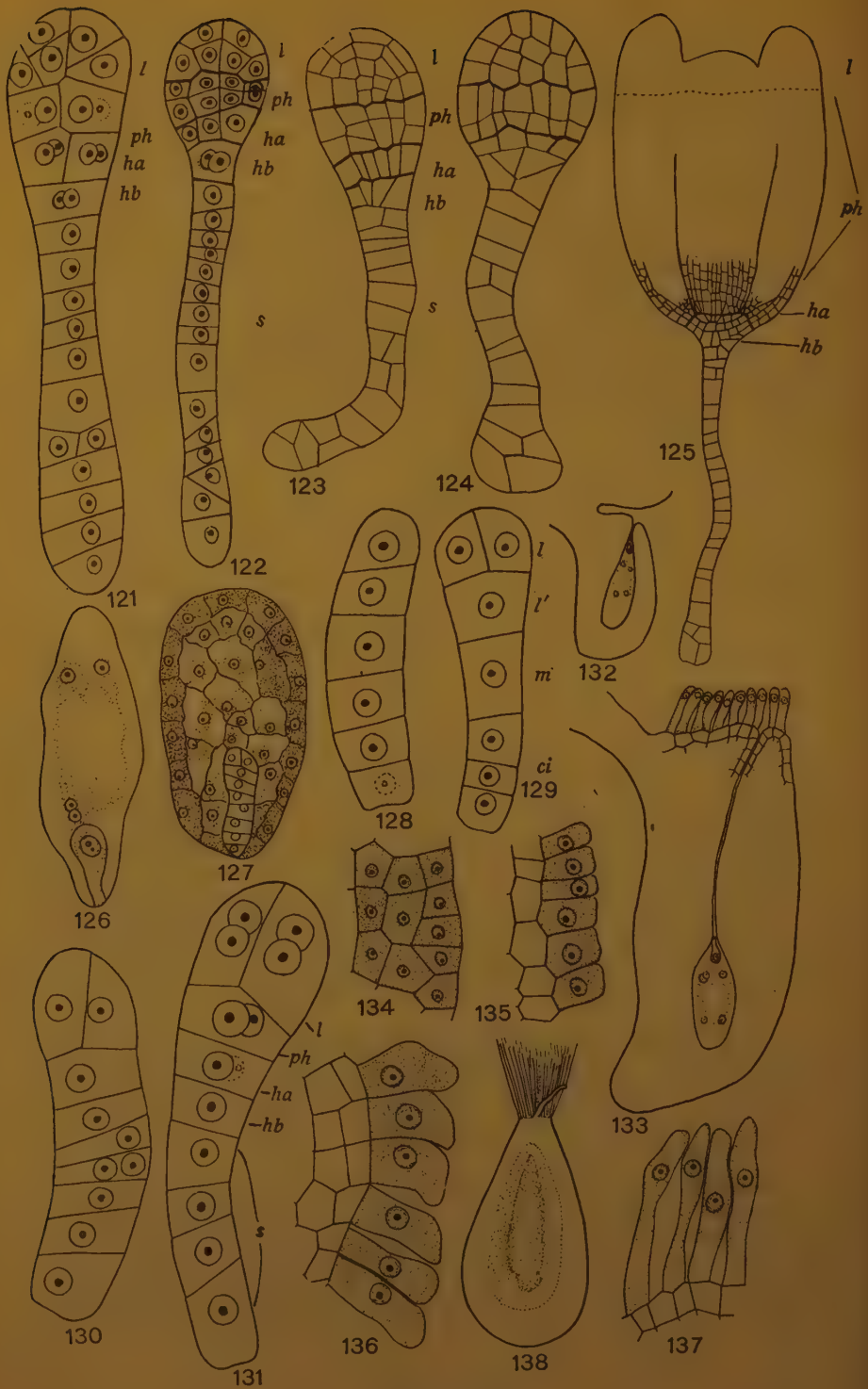
.. stem tip and cotyledons.
.. hypocotyl
.. root tip and part of root cap
.. part of root cap and upper part of suspensor.
.. suspensor.

l undergoes two vertical divisions in intersecting planes resulting in 4 juxtaposed quadrants (Figs. 117–119; 129–131). These dividing diagonally and later by periclinal divisions, form the dermatogen initials to the outside (Figs. 121–124). The two vertical divisions in *ph* result in a tier of 4 cells; these cells by another vertical division demarcate the dermatogen to the outside (Figs. 120, 121). The inner cells by further vertical divisions form the periblem and plerome initials of the stem (Figs. 123, 124). The derivatives of *ha* form the single layered root tip and part of the root cap and those of *hb* form some more layers of root cap and also the upper part of the suspensor (Fig. 125).

The mature embryo in both species is large and shows fleshy cotyledons. In *Cryptostegia*, the hypocotyl is cylindrical and the ovoid cotyledons are relatively large. In *Caralluma*, the hypocotyl is relatively larger and flattened and cotyledons smaller and auricular.

SEED DEVELOPMENT

One interesting feature of seed development is the formation of the coma or the group of hairs which help in seed dispersal. The development of the coma was followed in *Caralluma attenuata* (Figs. 133–138). The hairs develop after fertilisation from the epidermal cells around the micropyle and funicle (Figs. 133, 138). They considerably increase in size; their cytoplasm becomes denser and their nuclei more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FIGS. 121–138

FIGS. 121–125. Some more stages in the development of the embryo in *Cryptostegia grandiflora*. Fig. 121, ×715; Figs. 122–124, ×385; Fig. 125, ×195.

FIGS. 126–138. *Caralluma attenuata*. Fig. 126. Embryo-sac with fertilised egg and free nuclear endosperm, ×340. Fig. 127. Embryo-sac with a filamentous embryo and endosperm which has become cellular, ×185. Figs. 128–131. Early stages in the development of the embryo, ×715. Figs. 132 and 133. Ovules with fertilised egg, before and after the commencement of coma formation, ×195. Figs. 134–137. Stages in coma development, ×340. Fig. 138. Mature seed (only part of coma shown), ×15.

prominent (Figs. 134, 135). Gradually the cells become papillate and free from one another by a schizogenous splitting of their middle lamellæ (Figs. 136, 137). They then elongate rapidly; the cytoplasm becomes vacuolated and the nucleus migrates to the middle of the elongating hair. Hairs in the mature seed measure about 4–5 cm. in length.

The seed of *Caralluma attenuata* is ovate and provided with a membraneous wing. This wing is composed of the two epidermal layers enclosing a layer of large empty cells. In the ripe condition, the dry light seed is lifted up easily by the parachute-like mechanism of the hygroscopic comose hairs. In course of time the hairs get detached and the seed falls. A sudden descent, however, is checked by the wing.

DISCUSSION

While the structure of the ovule, development and structure of the embryo-sac, endosperm and seed are closely similar in the two species studied, they present a number of differences in the development of the anther and pollen as shown in the following table.

TABLE II

Cryptostegia grandiflora	*Caralluma attenuata*
1. Anthers 4-locular; loculi coalesce in pairs in mature anther.	Anthers 2-locular.
2. Anther tapetum multiseriate on the side of the connective; tapetal cells 2-nucleate.	Anther tapetum mostly uniseriate; tapetal cells 1-nucleate.
3. Sporogenous cells undergo a secondary increase.	Primary sporogenous cells function directly as spore mother-cells.
4. Pollen in tetrahedral or bilateral tetrads.	Pollen in linear tetrads.
5. Division of the sporocytes is simultaneous.	Division of the sporocytes is successive.
6. Wall of the sporocyte disorganises at telophase I; tetrads separate; individual pollen grains are provided with exine.	Wall of the sporocyte does not disorganise; it forms part of the wall of the microspores; tetrads united into a pollinium; individual pollen grains are not provided with exine but the whole pollen mass is cutinised.
7. Stomium median at the junction of the anther loculi.	Stomium in the terminal region of the anther loculus.

The above characters seem to be common to the respective sub-families to which the two species belong.

Wettstein (1901) and Rendle (1938) include in their Order Contortæ four families: Loganiaceæ, Gentianaceæ, Apocynaceæ and Asclepiadaceæ. Among them, Asclepiadaceæ is greatly specialised in relation to insect pollination. The two sub-families of this family, though agreeing in the presence of a unique translator mechanism, differ in details of its development and functioning. The presence of pollinia, suppression of the anther loculi, development of the stomium in the upper region of the anther, direct functioning of the primary sporogenous cells as the sporocytes, arrangement of the pollen in linear tetrads, etc., in Cynanchoideæ show that this sub-family is relatively more advanced than Periplocoideæ. It is doubtful if the 1-nucleate condition of the tapetal cells found in this sub-family can be regarded as derived but it is seen in a number of specialised families like Mimosaceæ, Boraginaceæ, Rubiaceæ and Orchidaceæ.

Though Asclepiadaceæ has advanced along the line of insect pollination, it does not show other features of specialisation commonly seen in other sympetalous families such as endothelium, embryo-sac, endosperm and suspensor haustoria.

Asclepiadaceæ shows interesting features of similarity with Orchidaceæ, the other angiospermous family which has specialised in relation to insect pollination. Their evolution may be regarded as homoplastic. The presence of gynostegium and pollinia are well-known points of similarity. Corresponding to the suppression of the stamens in Orchidaceæ, we find suppression of the anther loculi in Asclepiadaceæ. Two-nucleate tapetal cells are seen in the Diandreæ of Orchidaceæ and Periplocoideæ of Asclepiadaceæ and one-nucleate cells in Monandreæ and Cynanchoideæ. The presence of multiseriate endothecium and unvacuolated cytoplasm in the microspores at the time of division of microspore nuclei are further points of similarity.

A perusal of the embryological features of the different families of the order Contortæ shows that it is a heterogeneous assemblage of families, probably polyphyletic (Schnarf, 1931). There is closer resemblance between Loganiaceæ and Gentianaceæ on the one hand and Apocynaceæ and Asclepiadaceæ on the other. The first two agree in amœboid anther tapetum, integumentary tapetum and cellular endosperm. Apocynaceæ and Asclepiadaceæ resemble each other in secretory anther tapetum, 1-nucleate tapetal cells, 3-nucleate pollen grains, presence of pollinia or tetrads, massive integument without endothelium, absence of embryo-sac and endosperm haustoria, fusion of polar nuclei before fertilisation, nuclear endosperm and comose seeds. The embryological features support Hutchinson's (1926) separation of the two families into one order, the Apocynales.

Summary

Development of the anther, pollen, translator, ovule, embryo-sac, endosperm, embryo and seed have been studied in *Caralluma*

attenuata Wt. of Cynanchoideæ and *Cryptostegia grandiflora* R. Br. of Periplocoideæ, of the family Asclepiadaceæ.

The archesporium of the anther consists of a plate of cells, 6–10 in width and several in depth. The sub-epidermal cells of the anther wall develop into the fibrous endothecium and the innermost into the secretory anther tapetum. The tapetal cells are 1-nucleate in *Caralluma* and 2-nucleate in *Cryptostegia.* In the former, the primary sporogenous cells function directly, while in the latter they undergo a secondary increase. Cytokinesis is by cell plate formation in both; it is successive in *Caralluma* and simultaneous in *Cryptostegia.* Microspore tetrads are tetrahedral in *Cryptostegia* and linear in *Caralluma* and aggregated into pollinia. Pollen grains are 3-celled at the time of shedding.

Ovules are tenuinucellate, anatropous and unitegmic. The single archesporial cell functions directly as the megaspore mother cell. The lowest megaspore of the tetrad forms the embryo-sac according to the *Normal*-type. The synergids are hooked; polar nuclei fuse before fertilisation. Antipodals are insignificant and persist till the time of fertilisation. Starch is present in the embryo-sac.

Fertilisation is porogamous. Endosperm is nuclear and a little of it remains in the mature seed.

Embryo development conforms to the *Linu* -variation of the Solanad Type. The suspensor is long and almost uniseriate. The coma of seeds develops from the epidermal cells around the micropyle.

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